NASA CR- 152588

HUGHES

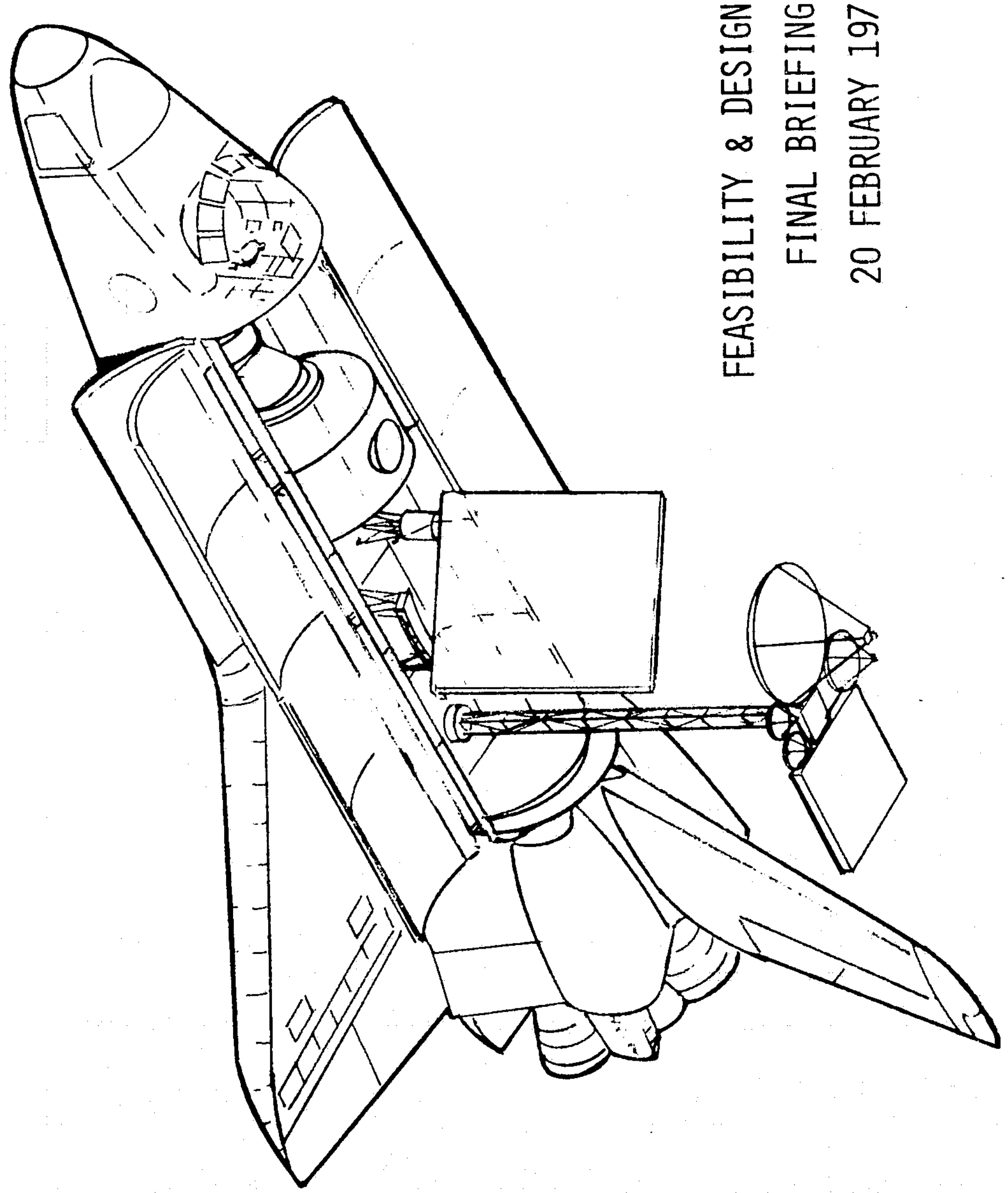
HUGHES AIRCRAFT COMPANY

METEOROLOGICAL RADAR FACILITY

FEASIBILITY & DESIGN STUDY

FINAL BRIEFING

20 FEBRUARY 1976



(NASA-CR-152588) METEOROLOGICAL RADAR FACILITY. PART 1: SYSTEM DESIGN Final Report (Hughes Aircraft Co.) 140 p HC A07/MF A01 CSCL 17I

N77-32219

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G3/16 49295

FINAL REPORT OF MRF STUDY

PART I SYSTEM DESIGN

Contract No. NAS5-22468

February 1976

HUGHES PERSONNEL

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HUGHES AIRCRAFT COMPANY

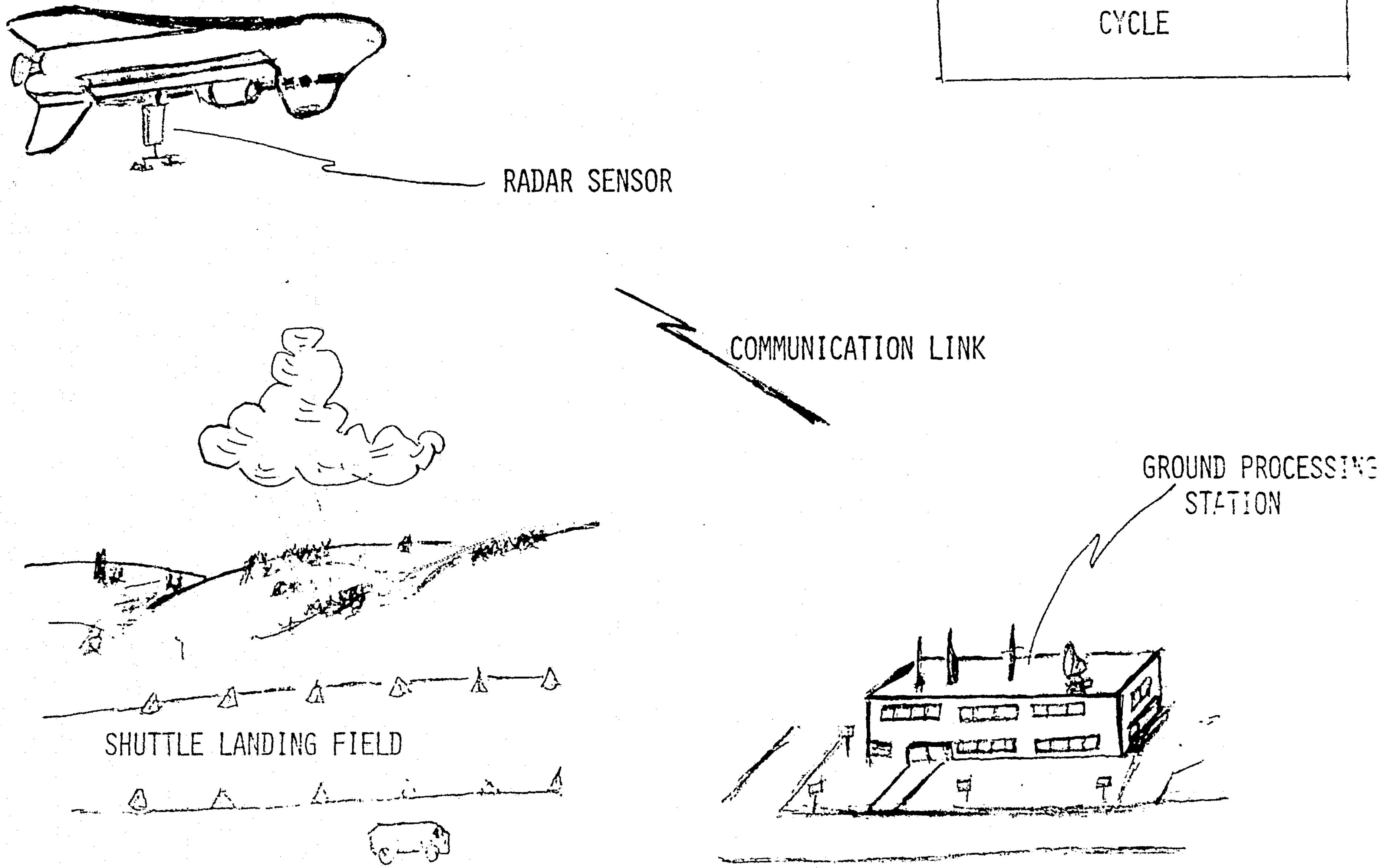
LLOYD L. BRASSAW JR.

SWEGN D. HAMREN

WILLIAM H. MULLINS

BERNARD P. SCHWEITZER

METEOROLOGICAL RADAR CYCLE



MRF TOPICS

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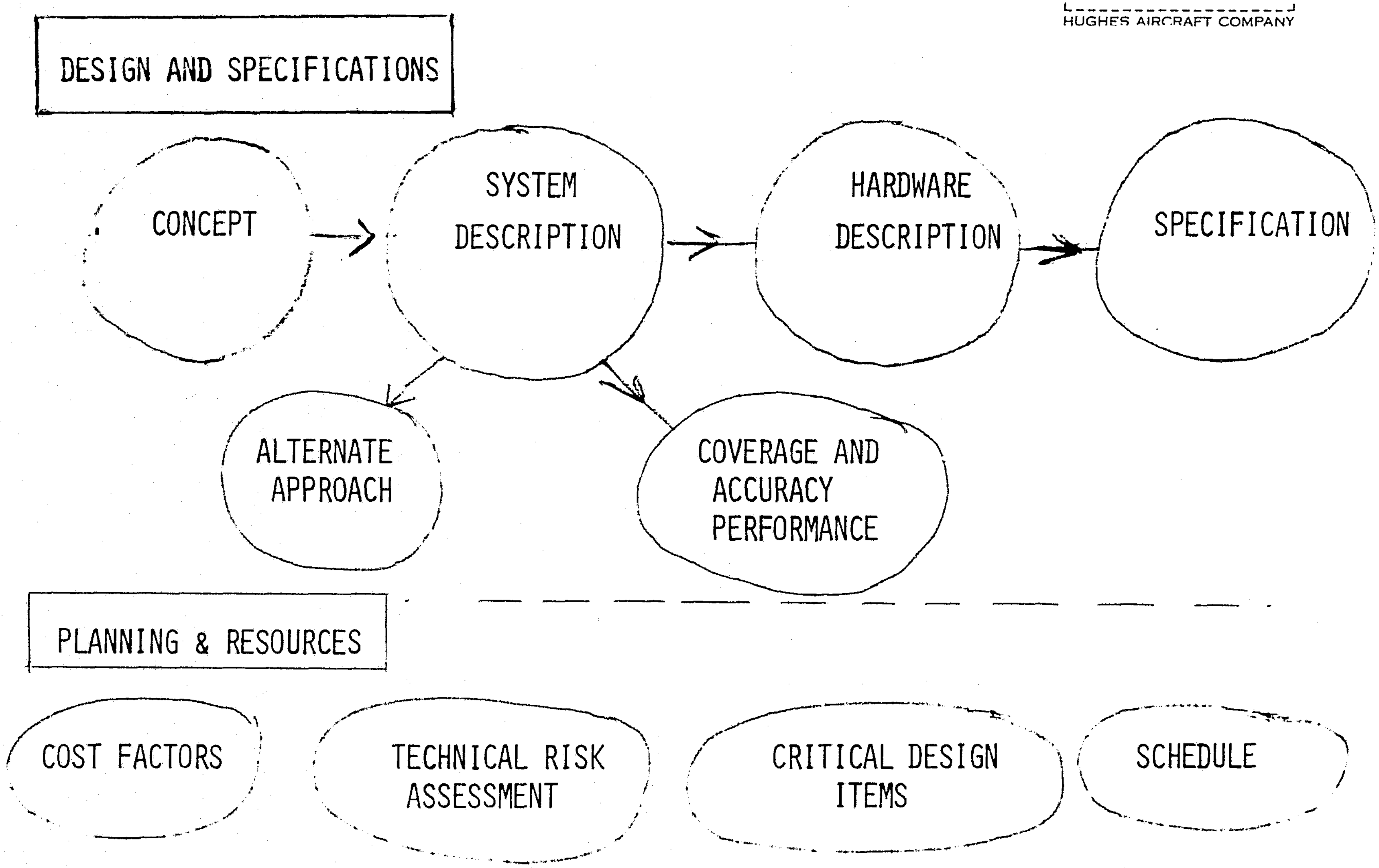

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BRIEFING OUTLINE - MORNING

1.	INTRODUCTION	9:15	L. BRASSAW
2.	OVERVIEW	9:30	B. SCHWEITZER
3.	WEIGHT/POWER/VOLUME ESTIMATES	10:30	W. MULLINS
	BREAK	10:45	
4.	CRITICAL DESIGN AREAS	11:00	MULLINS/HAMREN
5.	SYSTEM DESCRIPTION	11:20	SCHWEITZER/MULLINS
6.	MAJOR SYSTEM DESIGN DECISIONS	11:40	SCHWEITZER/MULLINS
	LUNCH		

BRIEFING OUTLINE - AFTERNOON

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7.	SYSTEM PERFORMANCE	1:30	W. MULLINS
8.	SUBSYSTEM DESCRIPTION	2:00	B. SCHWEITZER
	o ANTENNA	2:10	S. HAMREN
	o TRANSMITTER/RECEIVERS	2:40	W. MULLINS
	o PRE-PROCESSOR & RECORDER	2:55	W. MULLINS
9.	SYSTEM SPECIFICATIONS	3:10	W. MULLINS
10.	SUMMARY	3:30	L. BRASSAW
	BREAK	3:45	

OVERVIEW I

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- SUMMARY OF MRF FUNCTIONS
- SCHEDULE
- BISTATIC ANTENNA APPROACH
- SPATIAL GEOMETRY
- ACCURACY
- INSTALLATION
- COST
- RISK ASSESSMENT

SUMMARY OF MRF FUNCTIONS

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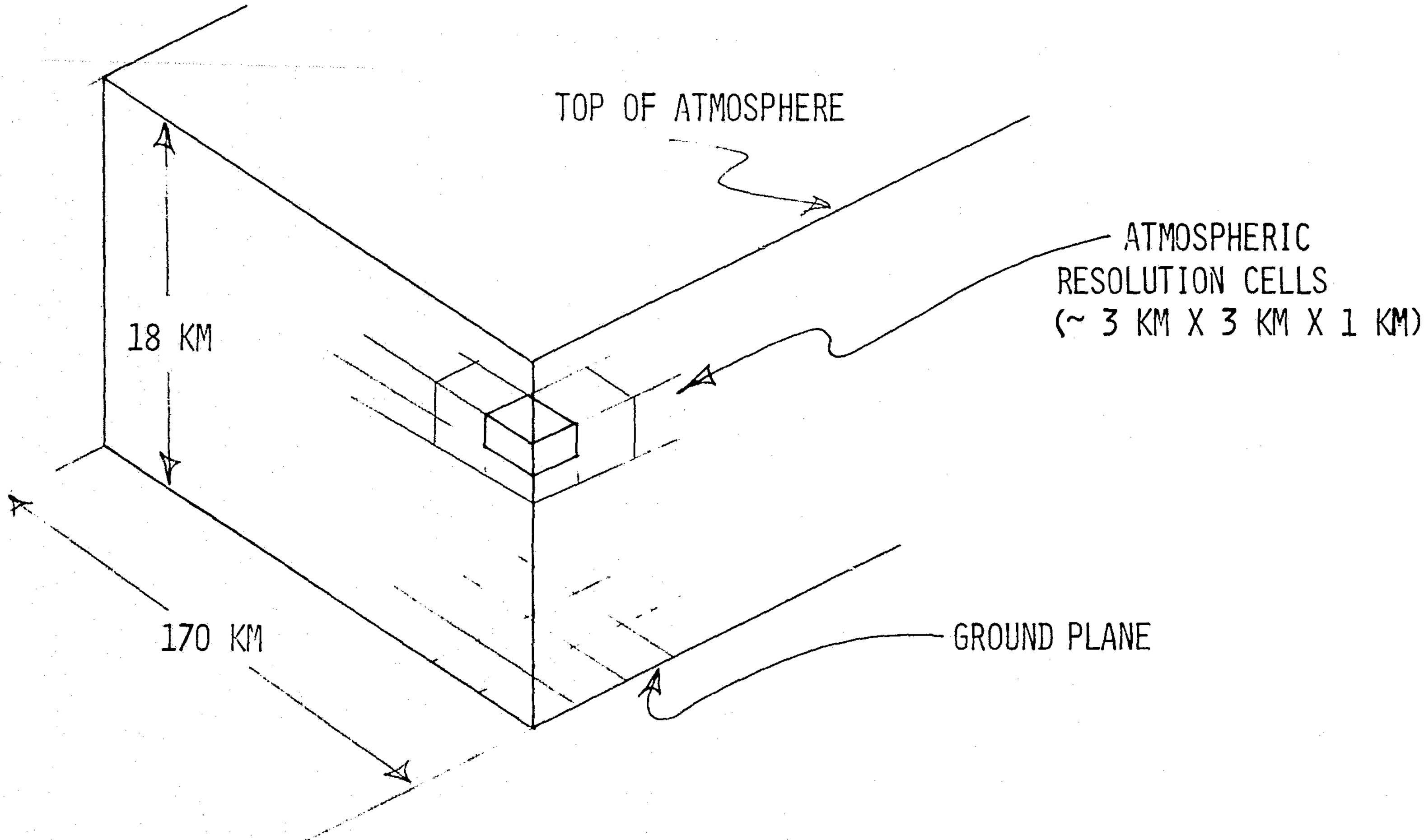
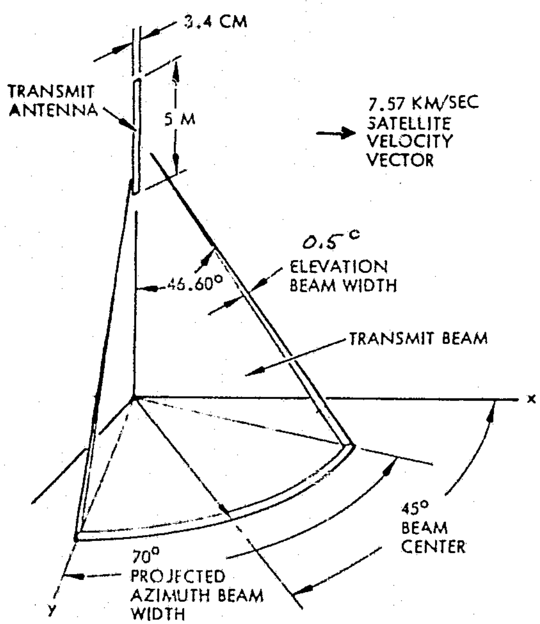
- THREE-DIMENSIONAL PRECIPITATION MEASUREMENTS
- GROUND MAP

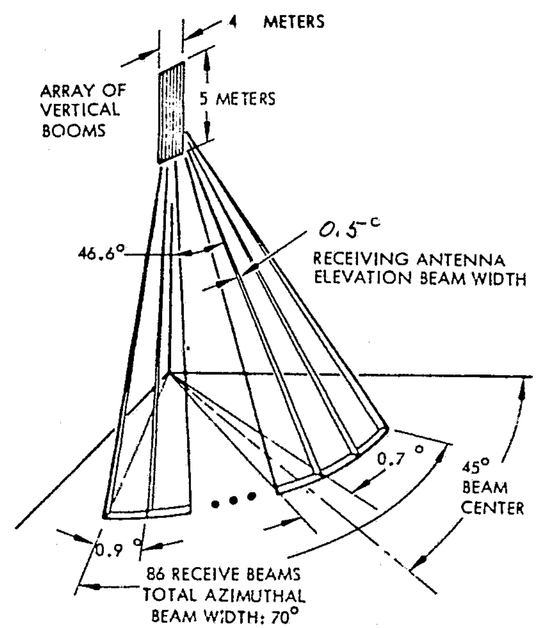
MRF THREE DIMENSIONAL PRECIPITATION DATA



BISTATIC ANTENNA APPROACH



TRANSMIT ANTENNA



RECEIVE ANTENNA

SPATIAL GEOMETRY

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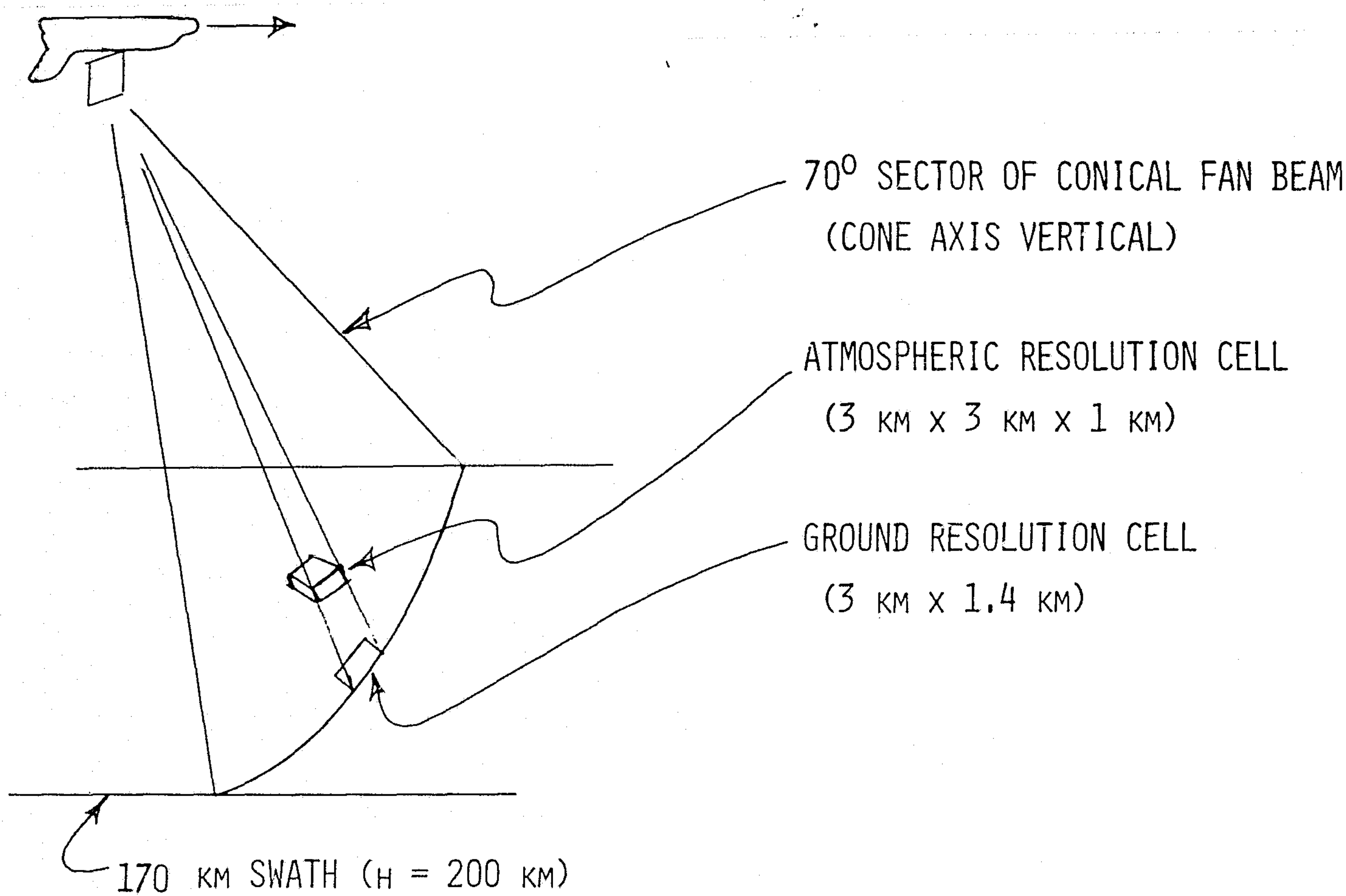

MRF EXPERIMENTAL PHASES

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PARAMETER	SUB-SCALE GOALS	FULL-SCALE GOALS
SPATIAL RESOLUTION (AZ X EL X R), KM	2.8 x 2.6 x 1	8.4 x 1.3 x 1
DOPPLER RESOLUTION	1 x 2 x 1	1 x 1 x 1
ORBIT ALTITUDE	200 KM	582 KM
SWATH WIDTH	170 KM	1000 KM
NUMBER OF AZIMUTH BEAMS	86	86
ANTENNA DIMENSIONS (H x W), M	5.8 x 4.3	35 x 4.3
NUMBER OF ANTENNAS	1	2

SCHEDULE

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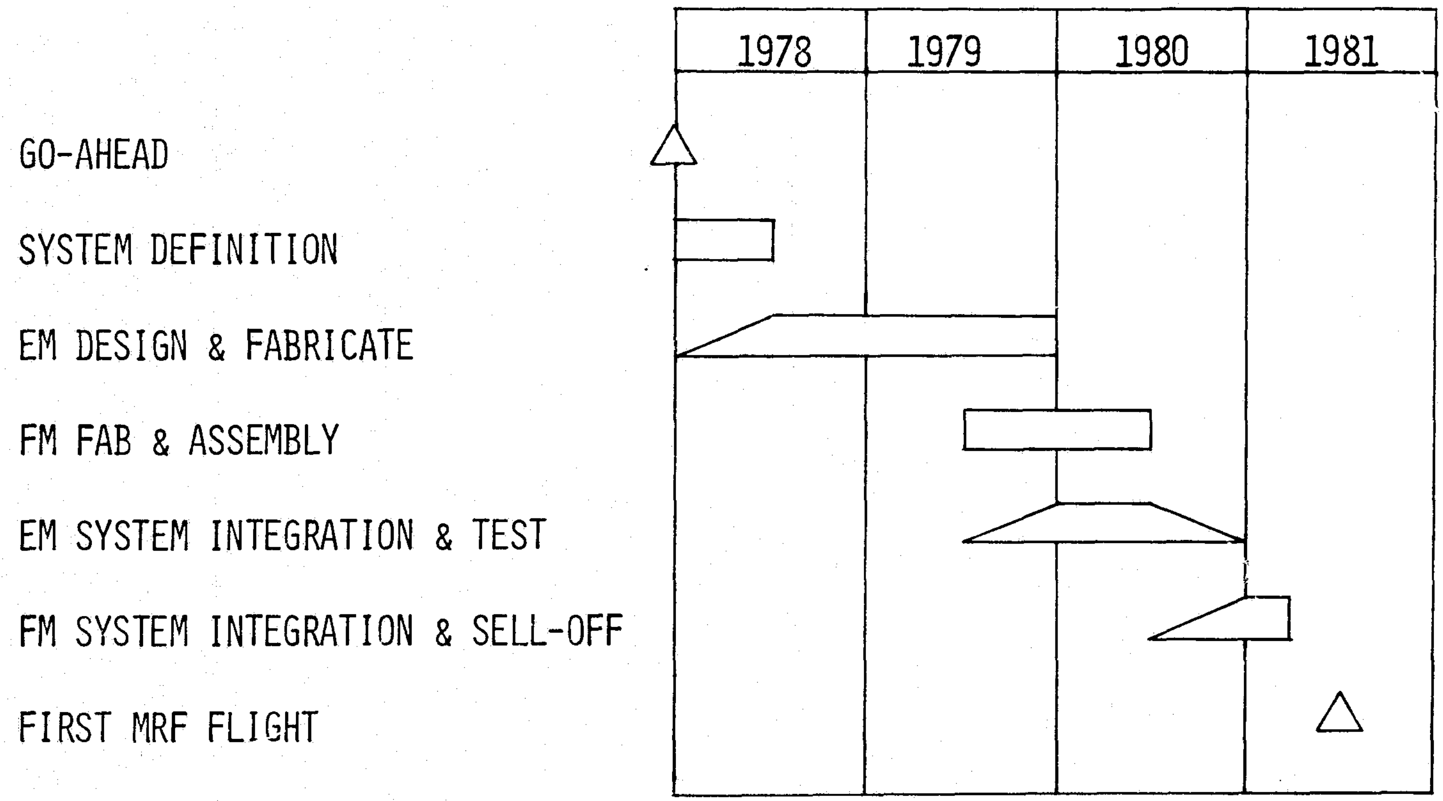
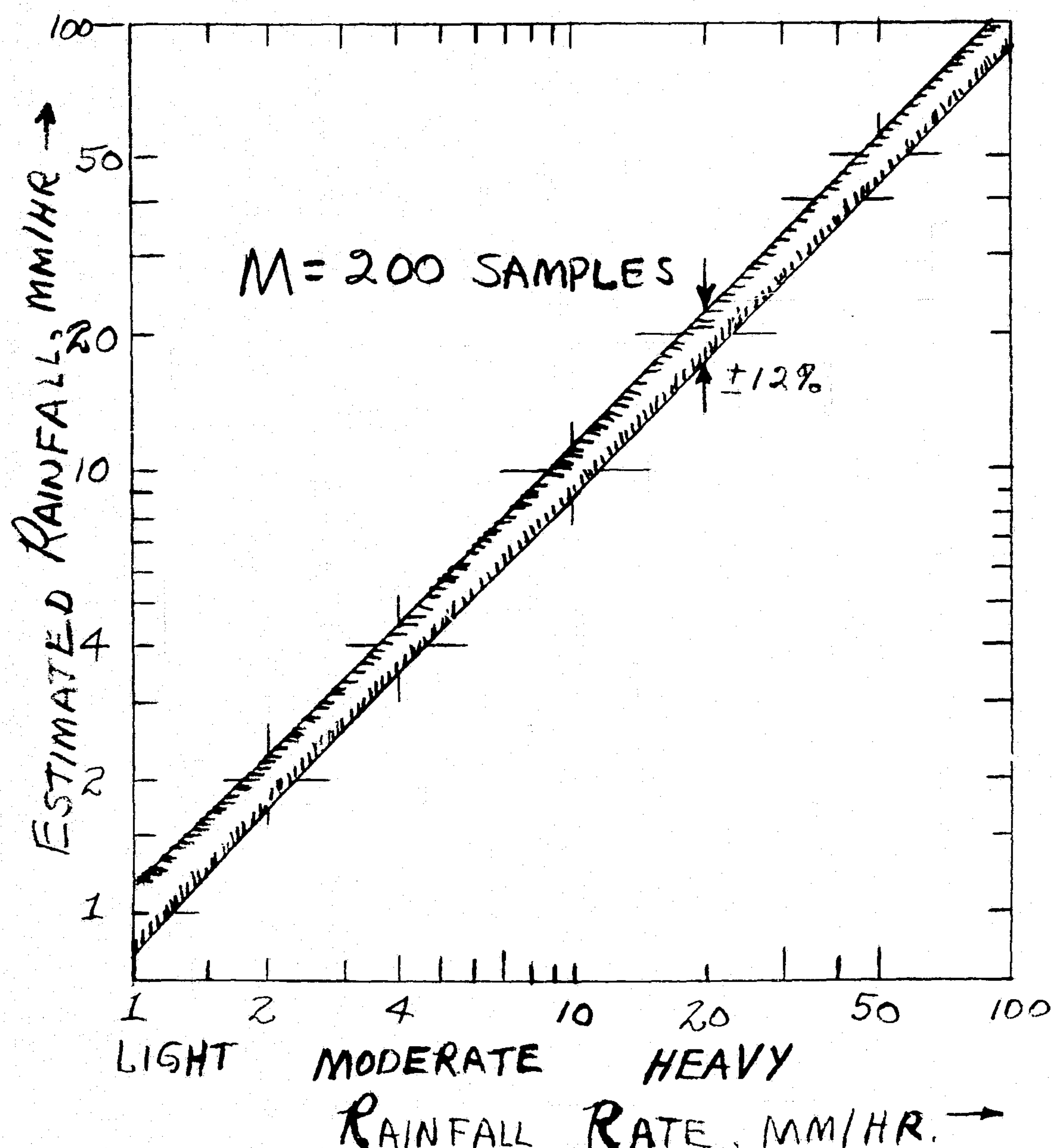
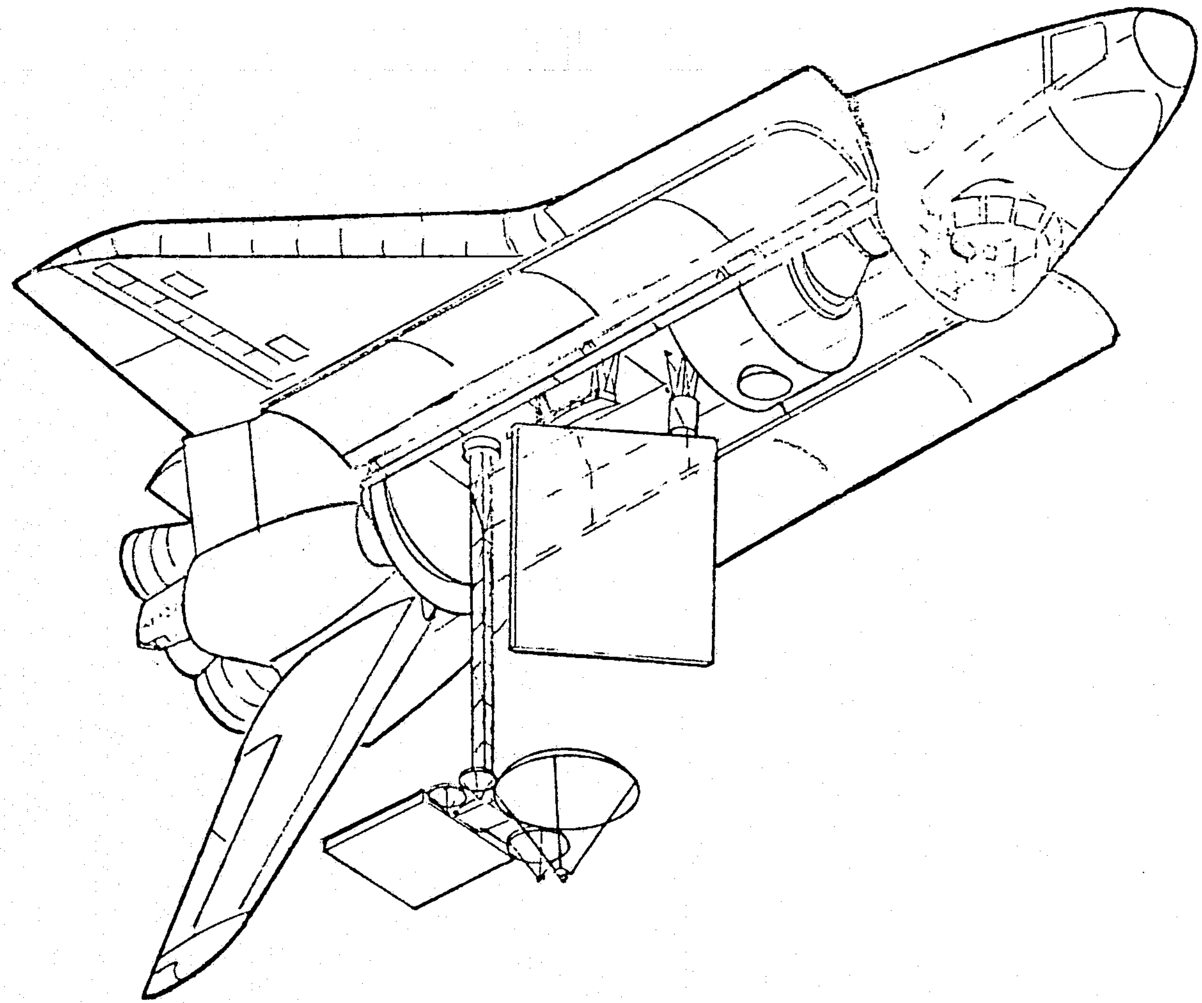


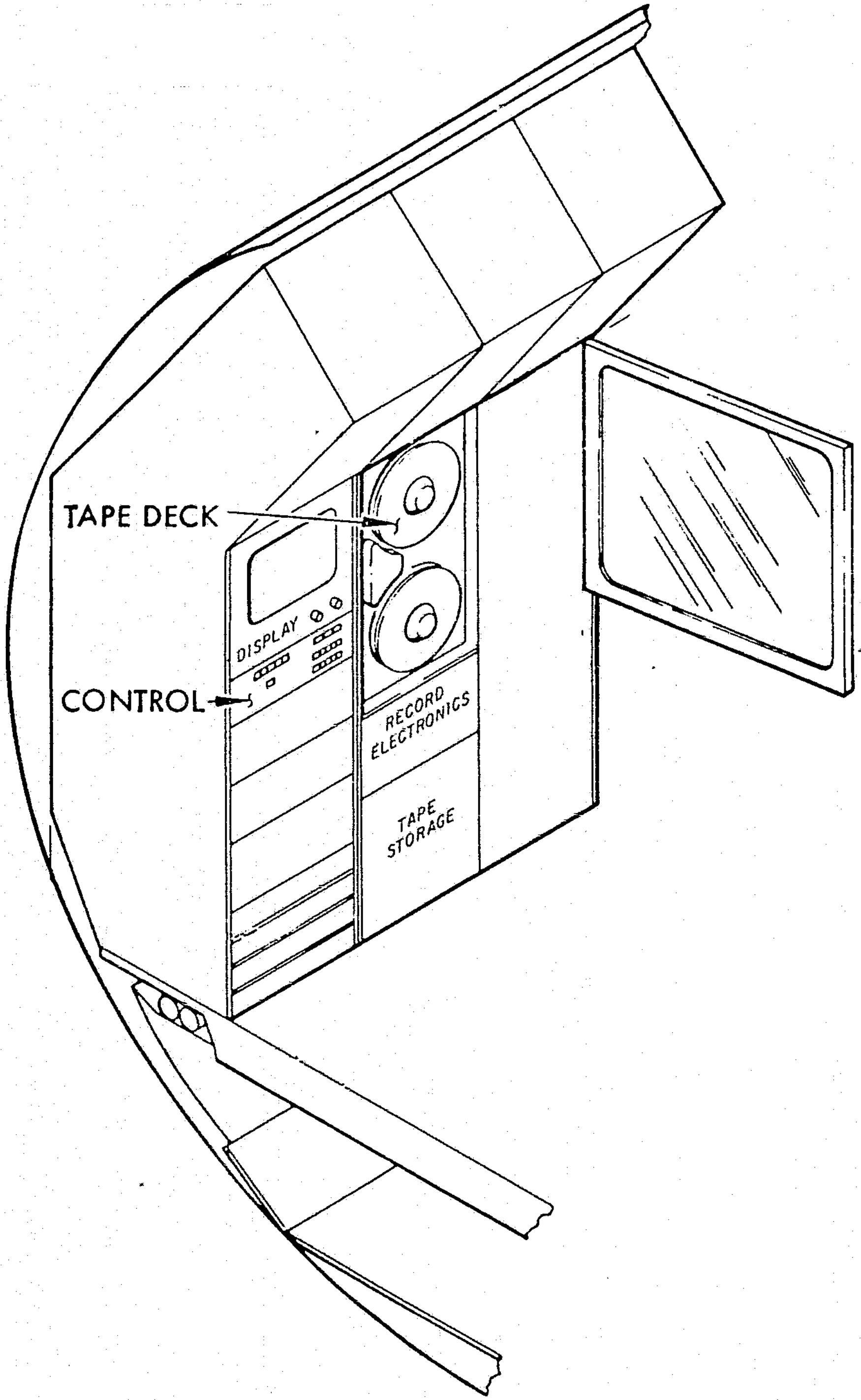


100
50
20
10
4
2
1
M = 200 SAMPLES
±12%
1
2
4
10
20
50
100
LIGHT
MODERATE
HEAVY
RAINFALL RATE, MM/HR.
ESTIMATED RAINFALL, MM/HR

ACCURACY

INSTALLATION





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RADAR EQUIPMENT IN MODULE

UNIT	DETAIL DESIGN	FABRICATION, ASSEMBLY & TEST	TOTALS
ANTENNA	18%	29%	47%
TRANSMITTER/RECEIVERS	5%*	13%	18%
PRE-PROCESSOR/RECORDER	9%	26%	35%
	32%	68%	100%

* ASSUMES TRANSMITTER DEVELOPMENT COST IS COVERED BY ANOTHER PROGRAM.

COST DRIVERS (SUB-SCALE SYSTEM)

- RESOLUTION
- SWATH WIDTH
- MEASUREMENT ACCURACY IN LOWER ATMOSPHERE
- DATA TIMELINESS

SPATIAL RESOLUTION COSTS

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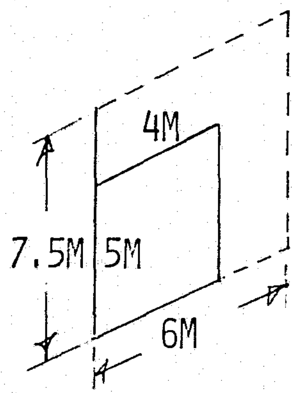
- ASSUMING X-BAND IS REQUIRED:



ANTENNA REQUIRED FOR 2 KM X 2 KM X 1 KM RESOLUTION (FABRICATION COST ~ 50% GREATER THAN BASELINE, PLUS FOLDING COST. 278 RECEIVE ELEMENTS.)

BASELINE ANTENNA (185 RECEIVE ELEMENTS)

- ASSUMING K_U-BAND (15 GHz) CAN BE USED:

    - ANTENNA ENVELOPE SAME AS X-BAND BASELINE. (FABRICATION COST ~ 50% GREATER. 278 RECEIVE ELEMENTS.)

- IN BOTH CASES: RECEIVER/PRE-PROCESSOR FABRICATION COSTS INCREASE BY ~ 50%.

SWATH COSTS

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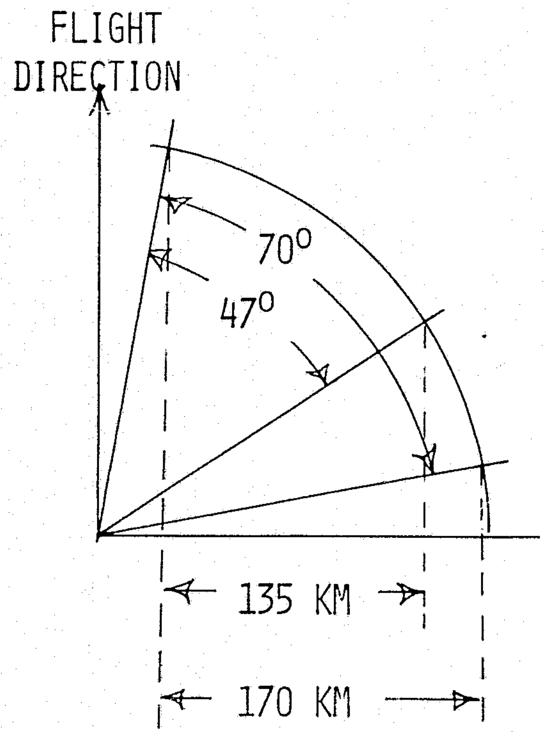
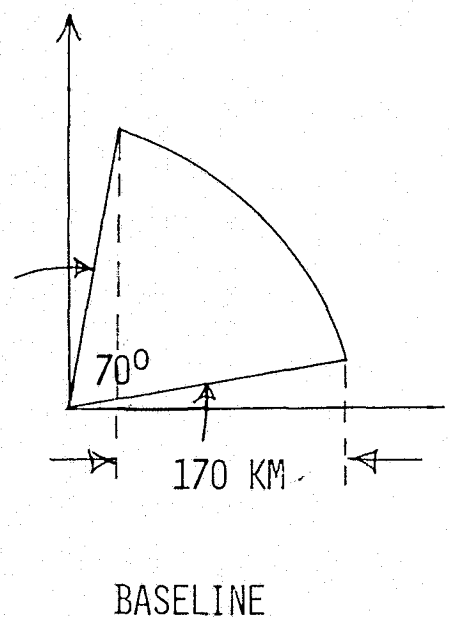
- A 20% REDUCTION IN SWATH WIDTH REDUCES THE NUMBER OF RECEIVER CHANNELS BY 34%.

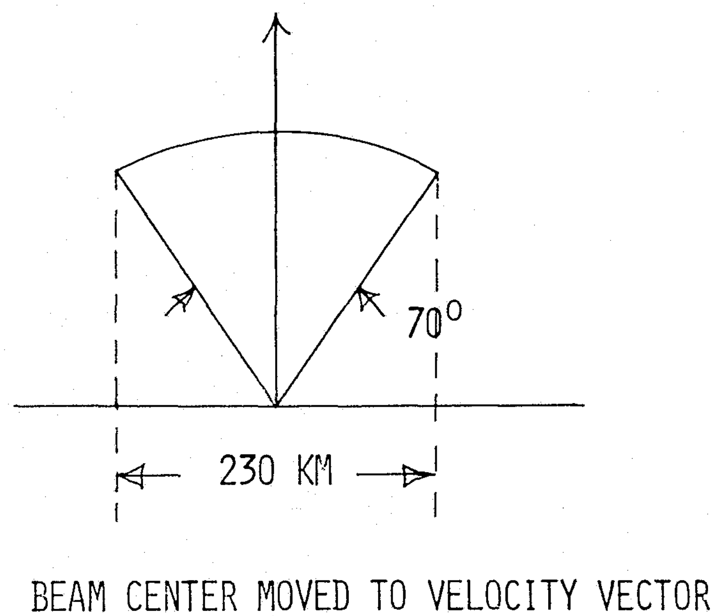


RECEIVER AND PRE-PROCESSOR FABRICATION COSTS REDUCED.

COST SAVINGS: ~ 7%.

- WITH REDUCED DOPPLER PROCESSING CAPABILITY:





- POINTING ANTENNA DIRECTLY AHEAD INCREASES SWATH WIDTH BY 35%.

MEASUREMENT ACCURACY IN LOWER ATMOSPHERE

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- ANTENNA VERTICAL ALIGNMENT SHOULD BE WITHIN 0.1° TO MAINTAIN MEASUREMENT ACCURACY IN LOWER ATMOSPHERE.

SENSING APPROACHES	
NONE-USE SHUTTLE ORIENTATION	NOT ACCEPTABLE: $\pm 2^{\circ}$ ERROR.
PAYLOAD SENSOR	$\pm .16^{\circ}$ (BEST ACCURACY, BASED ON 0.1° DEADBAND). SENSOR/ANTENNA ALIGNMENT ERROR. PROBABLY NOT ACCEPTABLE.
RADAR SENSOR (RECOMMENDED)	ACCURACY BETTER THAN $.01^{\circ}$ (NULLING SYSTEM). USE SHUTTLE YAW DATA. COST INCREMENT: ~ 3%.

CONTROL APPROACHES	
ROTATE SHUTTLE	$\pm .1^{\circ}$ DEADBAND CAUSES HUNTING.
ROTATE ANTENNA (RECOMMENDED)	FINE CONTROL POSSIBLE. VERY LOW POWER REQUIRED (~ 25 WATTS). REQUIRES EXTRA DEGREE OF FREEDOM FOR ANTENNA. COST INCREMENT: ~ 6%.

DATA TIMELINESS

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- 30 MINUTES OF PRECIPITATION DATA PER DAY PROJECTED. (10 REELS OF TAPE, AT 18 LBS/REEL, FOR A 10 DAY FLIGHT).
- TIME LAG BEFORE DATA IS PROCESSED AT GROUND STATION.
- TELEMETERING DATA DOWN REQUIRES TAPE PLAYBACK UNIT (AND SLOWDOWN).
- COST INCREASE FOR PLAYBACK UNIT: ~ 3%.

COST DRIVER SUMMARY

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	BASELINE	ALTERNATIVE	COST INCREMENT
SPATIAL RESOLUTION (KM)	3 X 3 X 1	2 X 2 X 1	20 TO 30%
SWATH WIDTH (KM)	170	(REDUCED BEAM-WIDTH) 135	7%
SWATH WIDTH (KM)	170	(ANTENNA RE-POINTED) 230	------
SWATH WIDTH (KM)	170	(ANTENNA RE-POINTED AND REDUCED BEAMWIDTH) 170	7.5%
MEASUREMENT BIAS IN LOWER ATMOSPHERE	0.6 dB AT 4 MM/HR.	3 dB AT 4 MM/HR.	9%

RISK ASSESSMENT

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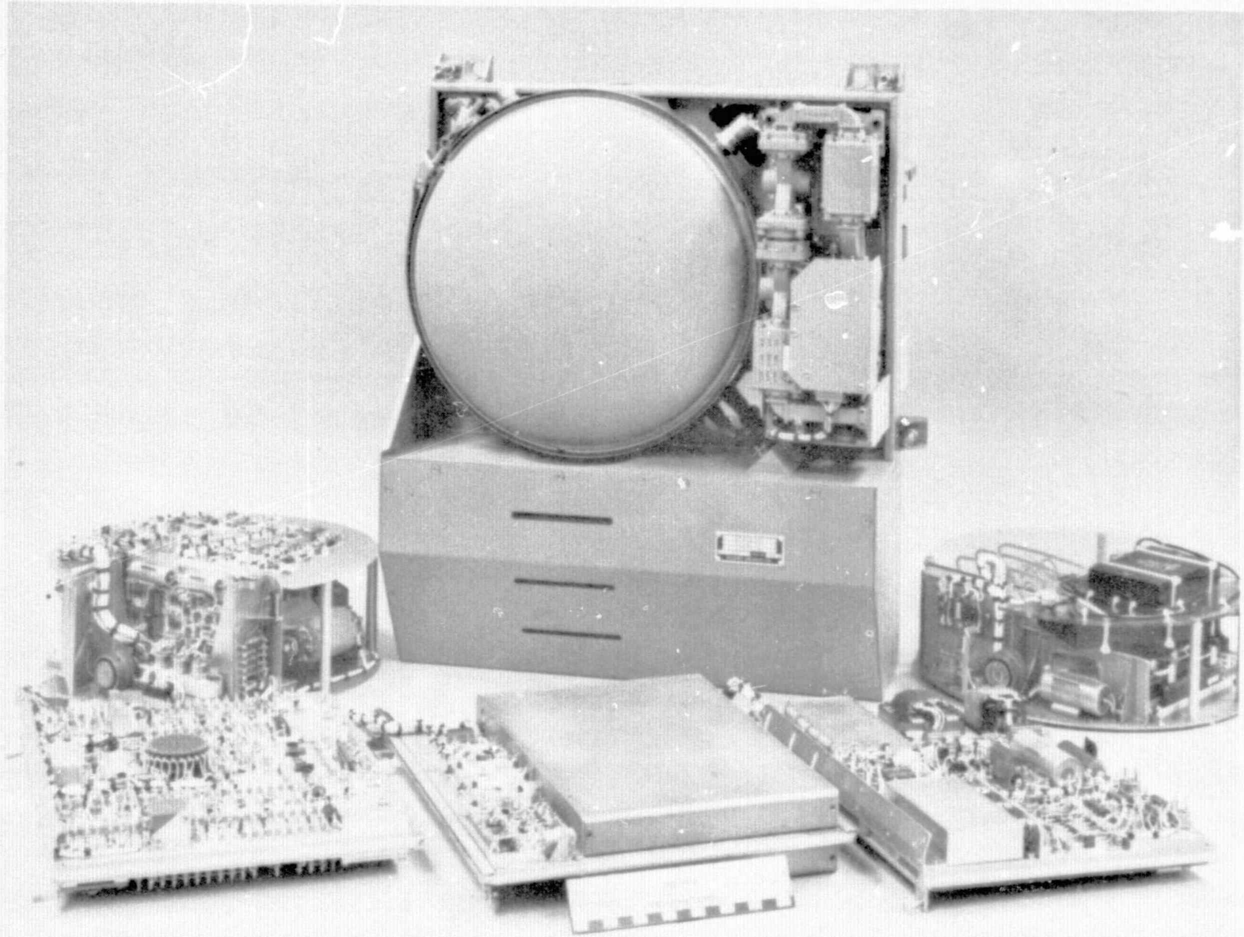
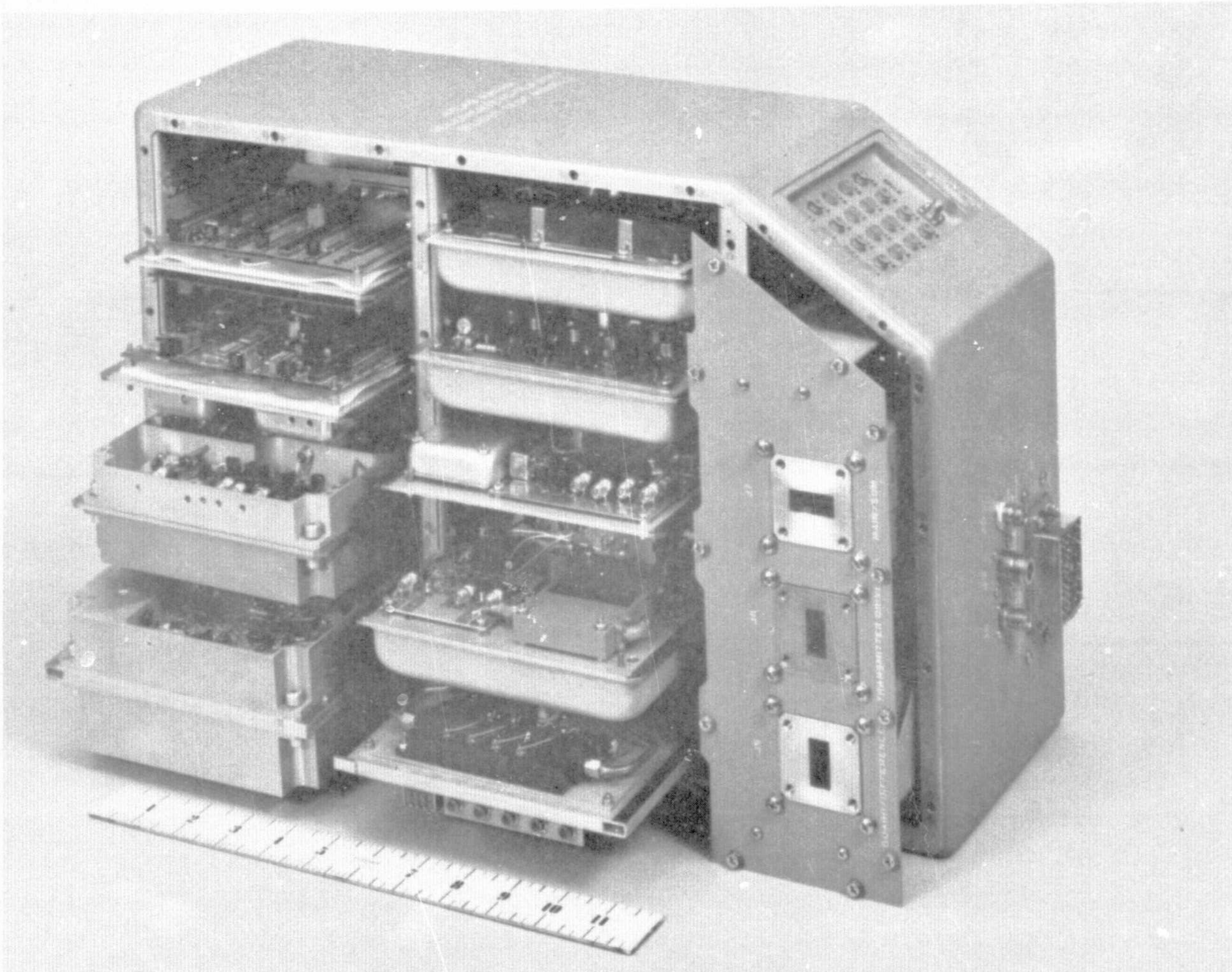
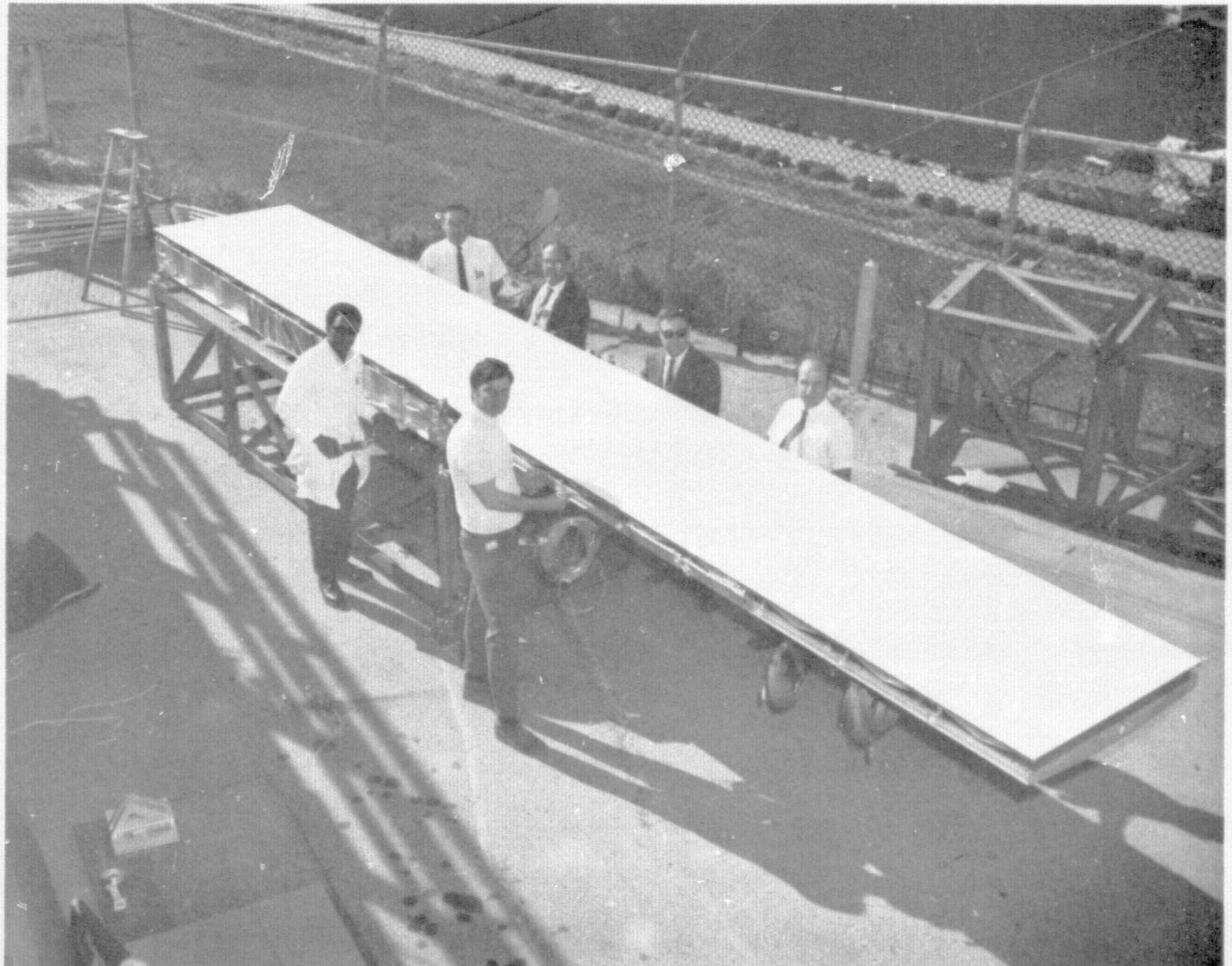
SUBSYSTEM	TECHNICAL RISK
ANTENNA	LOW
TRANSMITTER/RECEIVERS	LOW
PRE-PROCESSOR/RECORDER	VERY LOW
THERMAL CONTROL	VERY LOW







CRITICAL DESIGN ITEMS

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o MULTI-CHANNEL RECEIVER DESIGN TESTS

- LOW COUPLING AND GOOD PHASE BALANCE NEEDED

o ANTENNA STABILIZATION SENSOR DESIGN

- VERTICAL SENSING WITH RADAR

o ANTENNA SLOT TESTS

- LOW ANTENNA SIDELOBES NEEDED

o ANTENNA STRUCTURAL/THERMAL STUDIES

- LONG LEAD TIME ITEM

OVERVIEW II

- DATA FLOW
- OUTPUTS
- SYSTEM DUTY FACTOR
- GROUND PROCESSOR FUNCTIONS
- SELECTED SYSTEM PARAMETERS
- SELECTED PERFORMANCE PARAMETERS
- SUB-SCALE/FULL-SCALE COMPARISON

DATA FLOW

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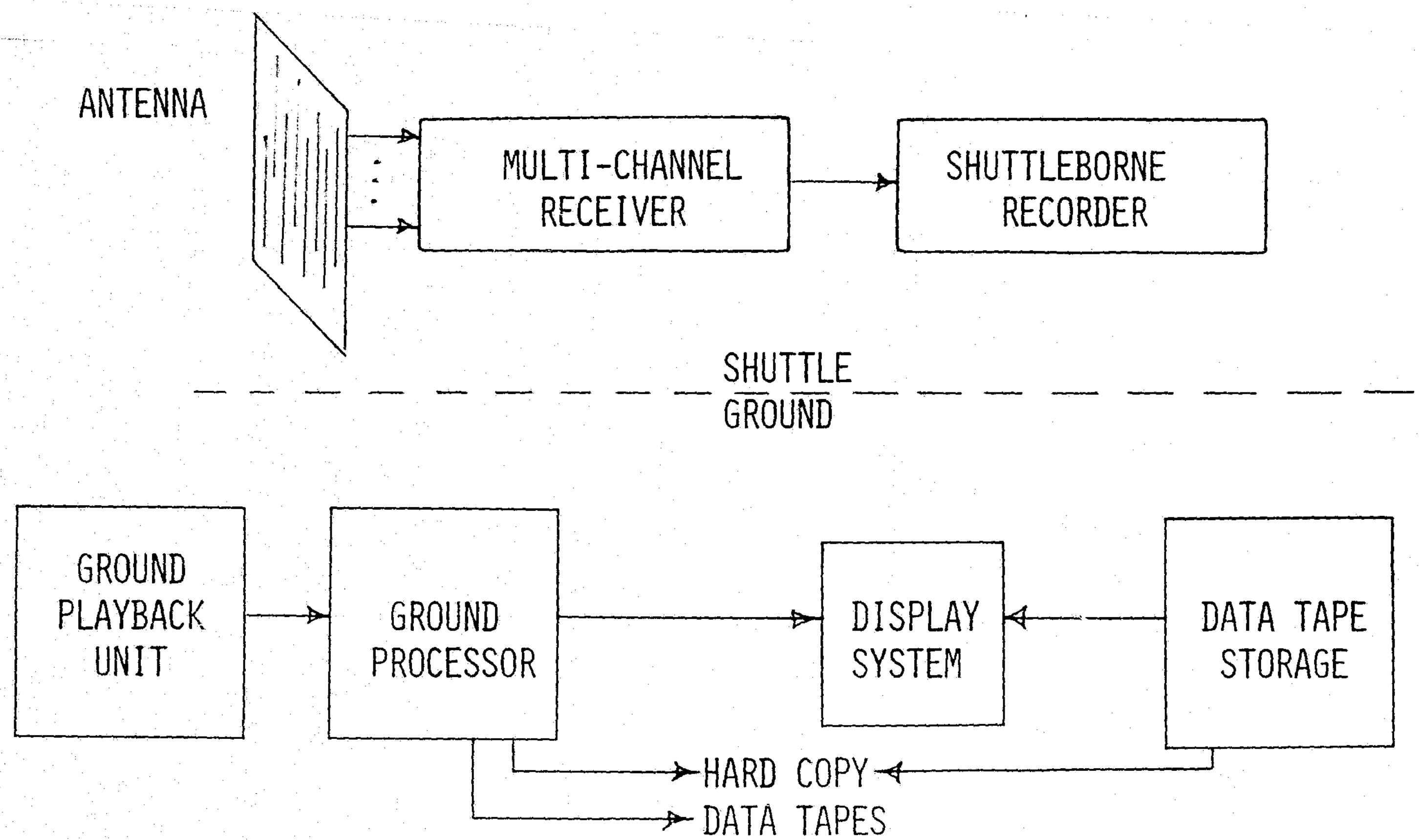

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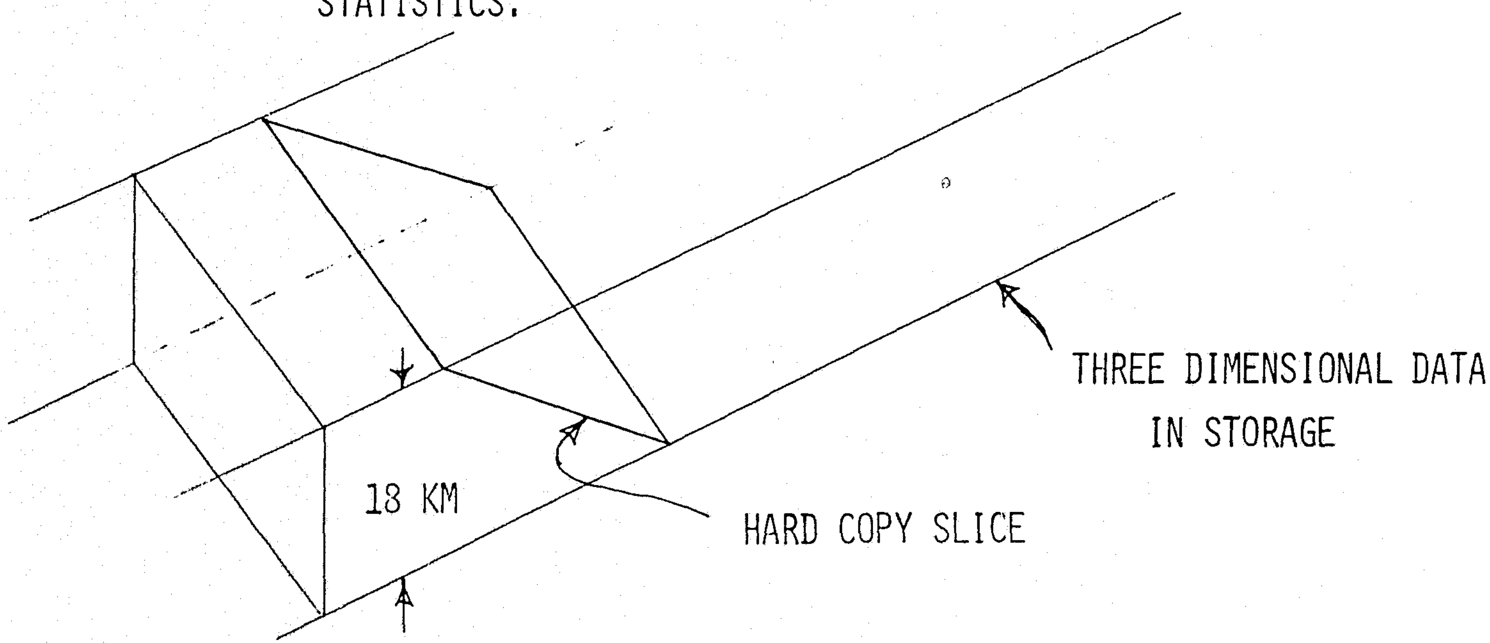
OUTPUTS

- o DATA TAPES: FORMATTED, EARTH COORDINATE REFERENCED,TIME-LABELED MEASUREMENTS OF PRECIPITATION AND SURFACE REFLECTIVITY.
- o HARD COPY: A TWO-DIMENSIONAL "SLICE" OF THE THREE DIMENSIONAL DATA. - DATA STATISTICS.



SYSTEM DUTY FACTOR

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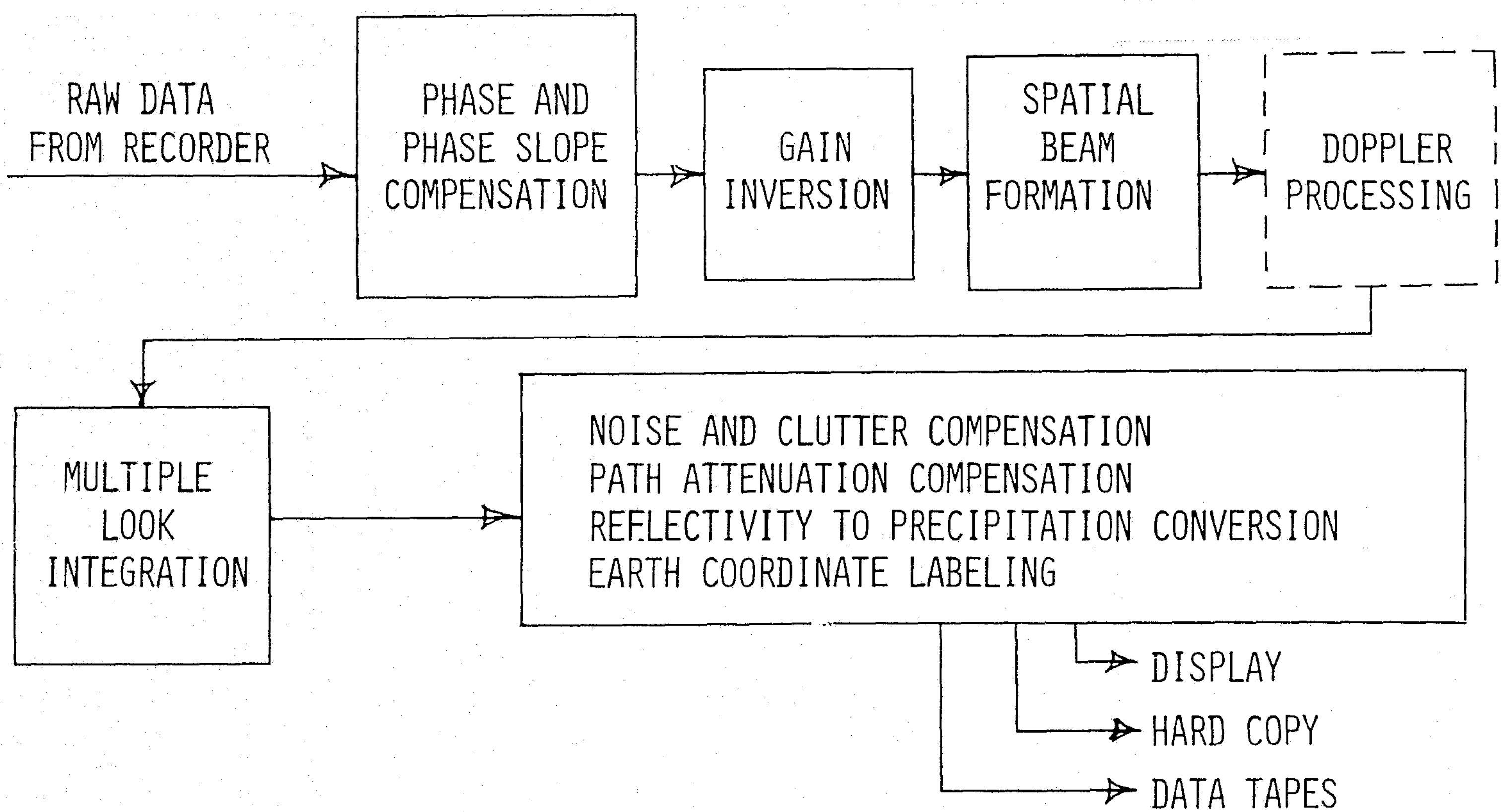
- SELECTED STORM SYSTEMS
- ALLOCATE 30 MINUTES/DAY AVERAGE (2%)
  (1 REEL = 30 MINUTES = 18 LBS.)
- MRF SENSOR PROGRAMMED BY SUMMARY MESSAGE ON COMMAND DATA LINK. BASED ON WEATHER NETWORK DATA.
- ALTERNATE PROGRAMMING APPROACH: USE ON-BOARD SENSOR-AUXILIARY OR MRF DERIVED.
- DUTY FACTOR IMPACTS ON MRF AVERAGE POWER CONSUMPTION & TAPE STORAGE REQUIREMENTS.

GROUND PROCESSOR FUNCTIONS



GROUND PROCESSING REQUIREMENTS

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- SPATIAL BEAM FORMATION MULTIPLICATION (FFT):

  10.3M REAL MULTIPLIES/KILOMETER

  78M REAL MULTIPLIES/SECOND (REAL TIME)

- REAL TIME PROCESSING REQUIRES ONE MASTER-SLAVE, PROGRAMMAGLE SIGNAL PROCESSOR

SELECTED SYSTEM PARAMETERS

OPERATING FREQUENCY	X-BAND
ORBIT ALTITUDE	200 ± 30 KM
SWATH WIDTH	170 KM
AVERAGE TRANSMITTED POWER	75 TO 150 WATTS
ANTENNA SIZE	4 M X 5 M
BEAM WIDTH:	
ELEVATION	0.5°
AZIMUTH	0.8° TO 0.9°
PULSE REPETITION FREQUENCY	3410 Hz, 6820 Hz
NUMBER OF RECEIVER CHANNELS	185

SELECTED PERFORMANCE PARAMETERS

MODE	REAL ARRAY
RESOLUTION	3 x 3 x 1 KM
SIGNAL TO TOTAL NOISE RATIO (FOR 4MM/HR)	6 dB
NUMBER OF INDEPENDENT SAMPLES	200
CALIBRATION ACCURACY*	1.2 dB AT 80% CONFIDENCE LEVEL
MEASUREMENT ACCURACY*	1.6 dB AT 80% CONFIDENCE LEVEL

*TEMPORAL CALIBRATION FACTORS OF .44 dB RSS INCLUDED

SUB-SCALE/FULL SCALE COMPARISON

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	SUB-SCALE AT 200 ± 30 KM	FULL SCALE AT 600 ± 30 KM
WAVELENGTH	3 CMS	3 CMS
RESOLUTION	3 x 3 x 1 KM	3 x 3 x 1 KM
ARRAY DIMENSIONS, V X H	5 x 4 M	15 x 12 M
NO. OF RECEIVE ELEMENTS	185	555
TRANSMITTER:		
PEAK POWER	8 KW	24 KW
AVERAGE POWER	75 WATTS	130 WATTS
PRF, Hz	3410 Hz	1970 Hz
BURST FREQUENCY, DUTY	227 Hz, .4	66 Hz, .4
SWATH WIDTH	170 KM	545 KM
NO. OF INDEPENDENT SAMPLES	200	120
SIGNAL-TO-TOTAL NOISE RATIO	6 dB	6 dB
MEASUREMENT ACCURACY*	1.6 dBz	1.8 dBz

*80% CONFIDENCE LEVEL WITH 1.2 dBz EQUIVALENT CALIBRATION ACCURACY

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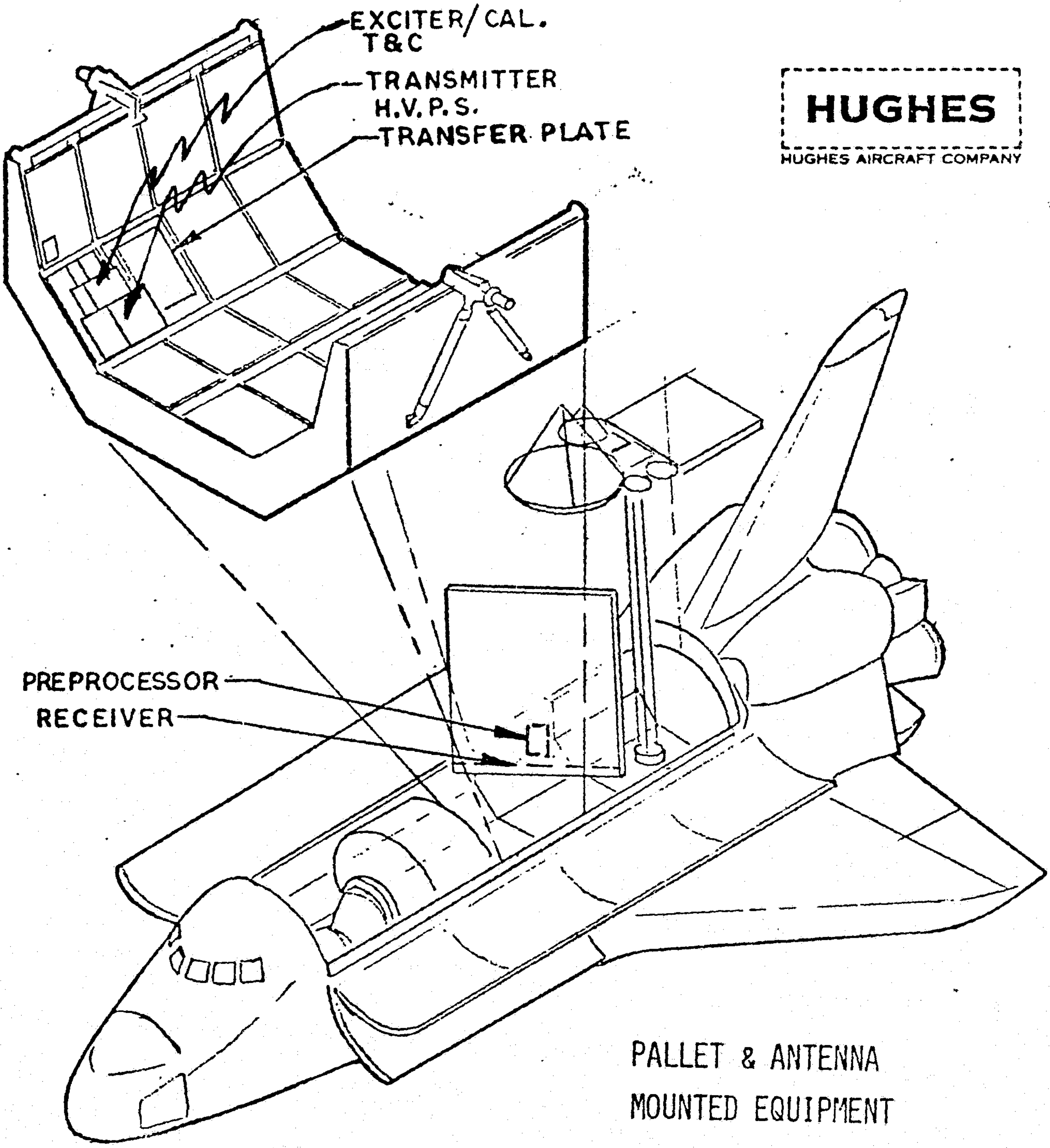
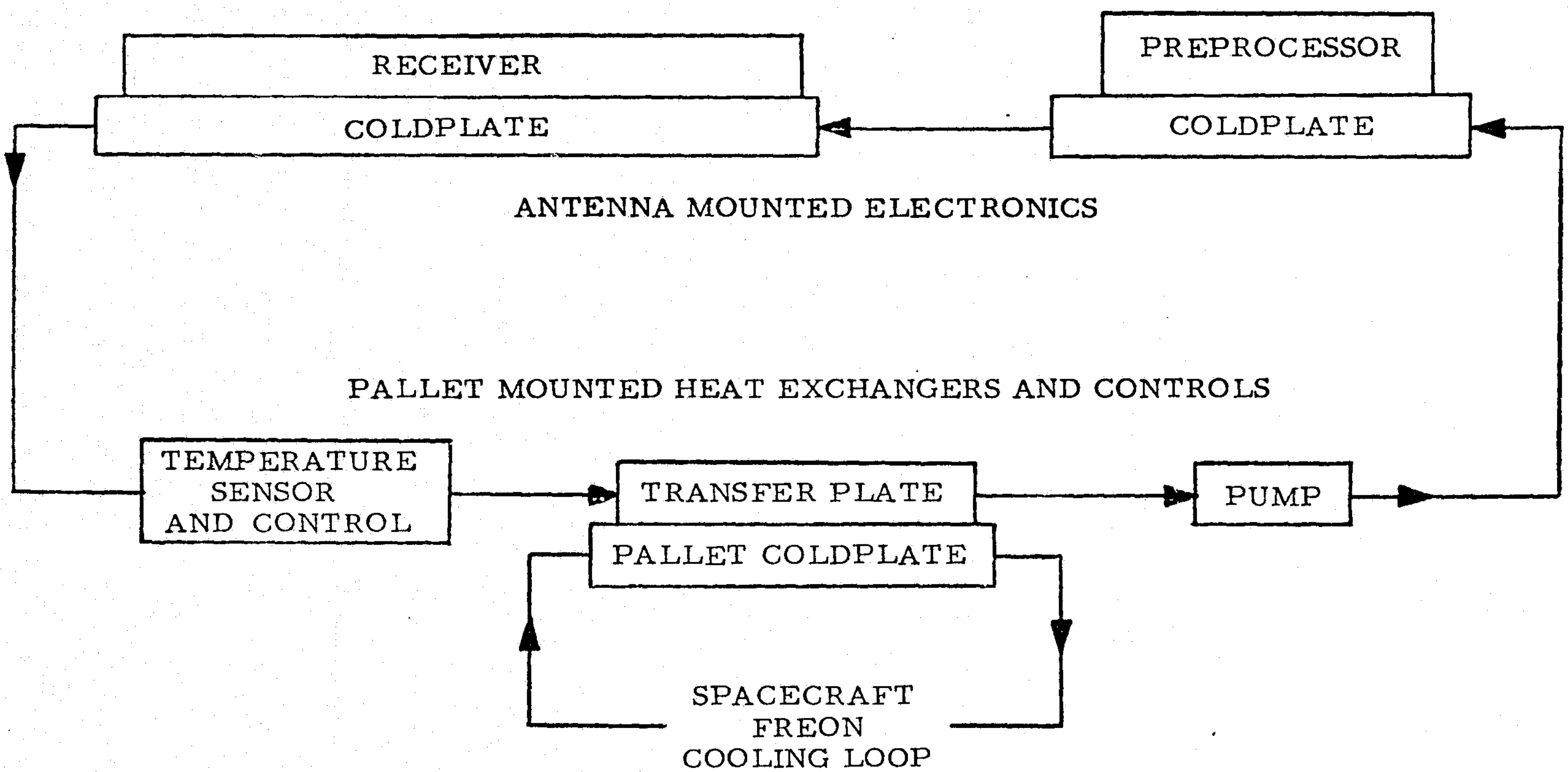


PALLET & ANTENNA
MOUNTED EQUIPMENT

POWER, WEIGHT, VOLUME ESTIMATES

EQUIPMENT	LOCATION	POWER WATTS	WEIGHT Kg (LB)	VOLUME M^3 (FT^3)
ANTENNA	PALLET BAY	30	275 (605)	6.1 (215)
TRANSMITTER, HVPS, LVPS, EXCITER, CALIBRATOR, TIMING & CONTROL	PALLET COLD PLATE	1530	83.6 (184)	.105 (3.71)
RECEIVERS, PRE-PROCESSOR,	ANTENNA REAR SURFACE	800	37.0 (81.4)	.06 (212)
THERMAL CONTROL	PALLET COLD PLATE		10.5 (23)	.019 (.68)
RECORDER, BUFFER/FORMATTER AND CONTROL	PRESSURIZED MODULE	680	108 (238)	.785 (27.7)
TOTALS		3040	51.1 (1131)	7.069 (249.6)



ANTENNA WATER COOLING LOOP

ELECTRONICS EQUIPMENT	MOUNTING LOCATION	THERMAL DISSIPATION (WATTS)	COOLING METHOD	WEIGHT Kg (POUNDS)	VOLUME M^3 (FT^3)	DIMENSIONS MM (IN)
RECEIVER	ANTENNA REAR SURFACE COLD PLATE	100	CONDUCTION TO COLDPLATE	25.2 (55.5)	.031 (1.09)	102 x 76 x 3993 (4 x 3 x 157.2)
PREPROCESSOR		700		11.8 (50.9)	.0287 (1.02)	254 x 686 x 165 (10 x 27 x 6.5)
TRANSMITTER AND HV POWER SUPPLY	PALLET COLD PLATE	950		43 (94)	.071 (2.49)	432 x 559 x 292 (17 x 22 x 11.5)
LV POWER SUPPLY		380		50	.013 (.451)	254 x 305 x 165 (10 x 12 x 6.5)
EXCITER/CALIBRATOR/ TIMING AND CONTROL		200		40	.021 (.752)	254 x 508 x 165 (10 x 20 x 6.5)
RECORDER	MODULE RACK	200	FORCED AIR	91 (200)	.713 25.2	530 x 1770 x 760 (20.86x69.68x29.92)
BUFFER/FORMATTER AND CONTROL		480		17.3 (38)	.072 (2.53)	572 x 165 x 760 (22.52x6.5x29.92)
TRANSFER PLATE, PUMP & TEMPERATURE CONTROL	PALLET COLD PLATE	INCLUDED IN RECEIVER AND PREPROCESSOR	CONDUCTION TO COLDPLATE	10.5 (23)	.019 (.68)	880 x 861 x 25.4 (34.6 x 33.9 x 1)

- AREAS REQUIRING LONG LEAD TIME.
- AREAS IN WHICH ADDITIONAL DEVELOPMENT OR TRADE-OFF IS NECESSARY FOR REDUCTION OF COST OR TECHNICAL RISK.

CRITICAL DESIGN AREAS

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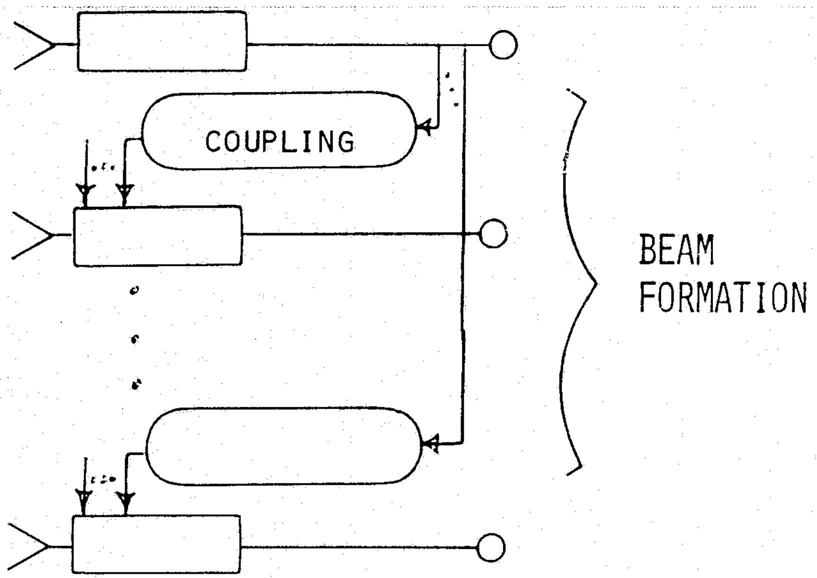
- MULTI-CHANNEL RECEIVER DESIGN TESTS
- ANTENNA STABILIZATION CIRCUIT DEVELOPMENT
- ANTENNA ELECTRICAL DESIGN
- ANTENNA STRUCTURAL/THERMAL DESIGN

PHASE & PHASE SLOPE MATCHING

- AZIMUTH SIDELOBE PERFORMANCE REQUIRES 4° (1σ) PHASE AND PHASE SLOPE MATCHING.
- MATCHING CAN BE ACHIEVED BY FEEDBACK CONTROL, USING CALIBRATE SIGNAL, ON-BOARD, OR BY PHASE CORRECTION IN THE GROUND PROCESSOR.
- COST AND TECHNICAL RISK OF THESE APPROACHES SHOULD BE COMPARED.

INTERCHANNEL ISOLATION



- o 184 COUPLING PATHS TO EACH CHANNEL
- o SUMMATION OF 185 OUTPUTS FOR BEAM FORMATION
- o -70 dB ISOLATION REQUIREMENT FOR COHERENT COUPLING (GRATING LOBE FORMATION)

- o CIRCUIT DESIGN MUST MINIMIZE INTER-CHANNEL COUPLING - IN PARTICULAR, COHERENT COUPLING.

ISOLATION PROBLEM

- SIGNAL CROSS-TALK PRODUCES SIDE-LOBES.

CROSS-TALK	ISOLATION REQUIREMENT	EFFECT
UNCORRELATED	-35 dB	NOISE LIKE
PARTIALLY CORRELATED	-58 dB	MIXED
TOTALLY CORRELATED	-81 dB	GRATING LOBES

- APPROACH: DESIGN FOR -66 dB ISOLATION.

ANTENNA STABILIZATION CIRCUIT DEVELOPMENT

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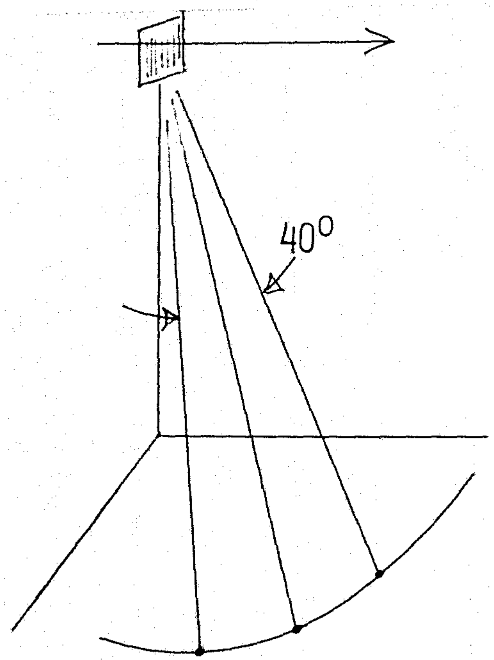
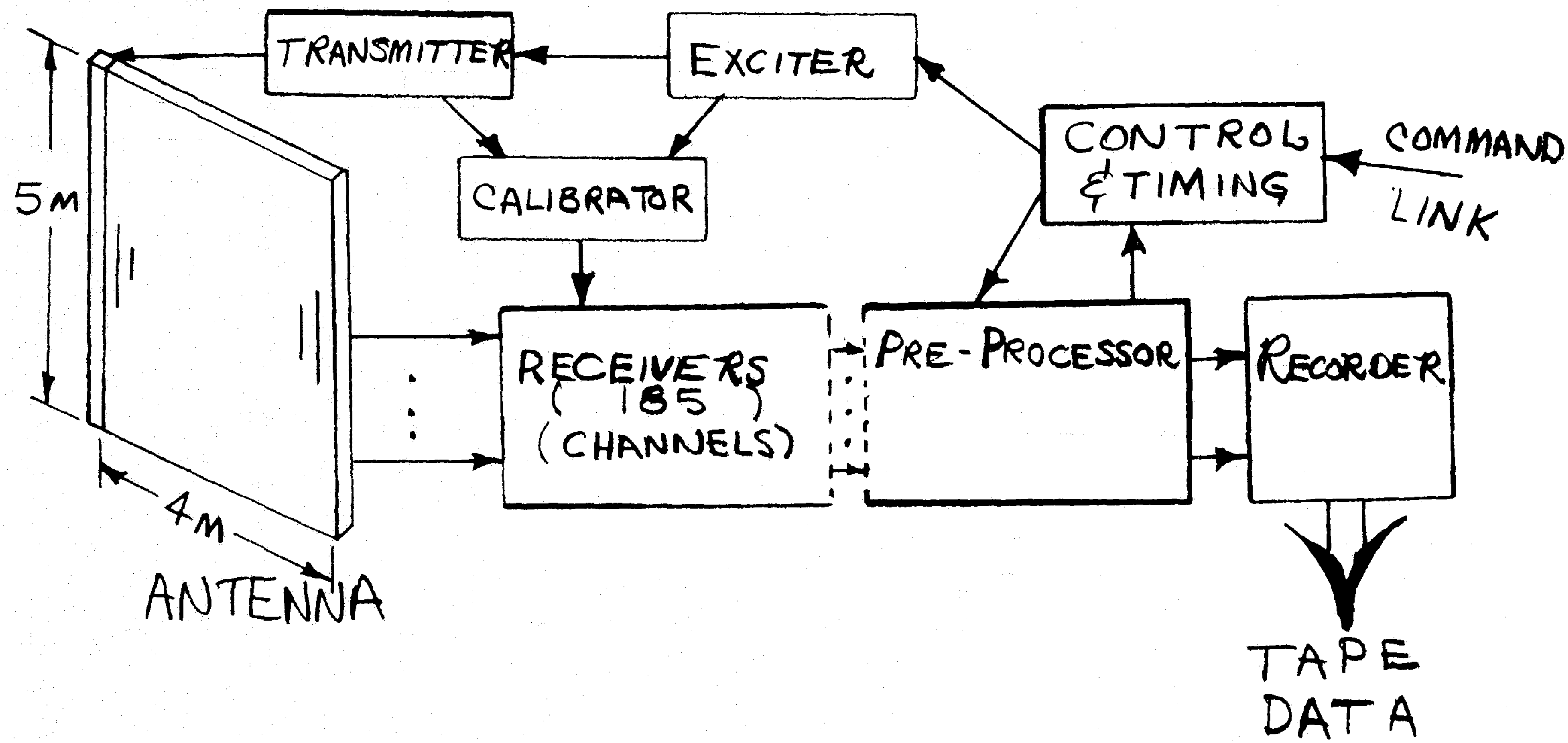


- FORM 3 BEAMS (0^o, $+20^o$, -20^o)
- ADJUST A/D TIMING SO THAT 0^o BEAM SAMPLE OCCURS AT ATMOSPHERE/TERRAIN THRESHOLD.
- ROTATE ANTENNA SO THAT SAME A/D SAMPLES OCCUR AT ATMOSPHERE TERRAIN THRESHOLD FOR $\pm 20^o$ BEAMS.
- ANTENNA VERTICAL AXIS IS THEN NULLED TO LOCAL VERTICAL.

- NEED SERVO-DYNAMIC DESIGN OF STABILIZATION CONTROL SYSTEM.

TOPICS:

- SPACE SYSTEM ELEMENTS
- CALIBRATION
- SYSTEM PARAMETERS
- BURST TIMING
- SENSITIVITY TO ORBITAL VARIATION
- ELEVATION PATTERN/ RESOLUTION/ SURFACE CLUTTER/ DOPPLER MODE
- DATA RATES


TRANSMITTER
EXCITER
CALIBRATOR
CONTROL & TIMING
COMMAND LINK
5m
4m
ANTENNA
RECEIVERS (185 (CHANNELS)
PRE-PROCESSOR
RECORDER
TAPE DATA

CALIBRATION:

$P_T \cdot GAIN_, = CONSTANT\ (K_R)$ AT A/D CONVERTER

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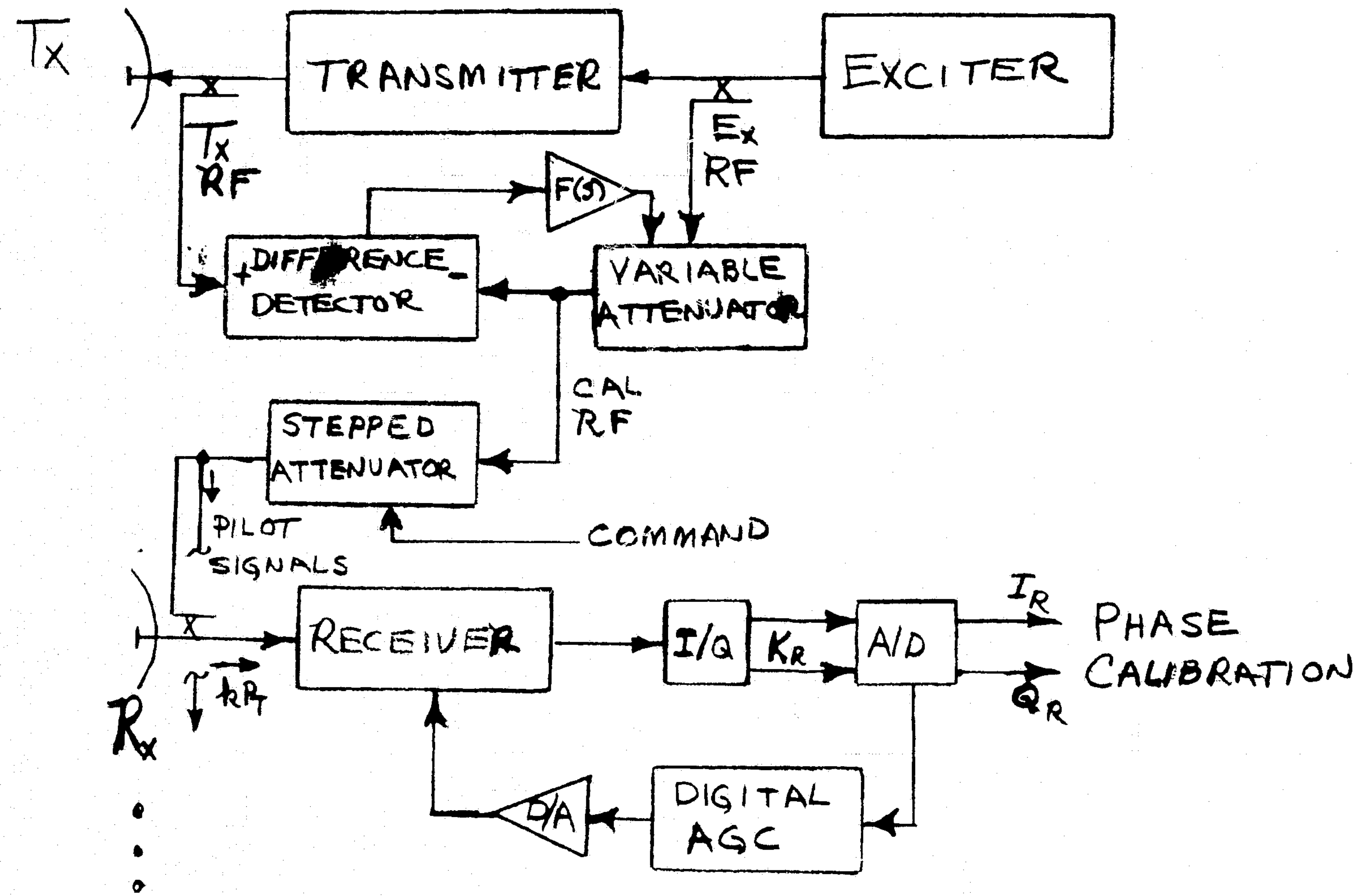

SYSTEM PARAMETERS (1)

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ANTENNA:	5 x 4 M
FREQUENCY:	10 GHZ
ANTENNA ORIENTATION:	VERTICAL & 45^{o} TO ORBIT PLANE
VERTICAL BEAM:	$\sim .5^{o}$ TILTED AT 46.6^{o} FROM THE NADIR
HORIZONTAL BEAMS:	$\sim .7^{o}$ AT 10^{o} & 80^{o} TO $\sim .9^{o}$ AT 45^{o} IN THE AZIMUTH PLANE
NO. OF RECEIVE ANTENNA ELEMENTS:	185 (HORIZONTAL PLANE)
RANGE RESOLUTION:	1 KM
SPATIAL RESOLUTION (H = 200 KM):	
	EL: 2.8 KM
	AZ: 2.7-3.3 KM
NO. OF AZIMUTH BEAMS:	$\geqslant 82$

SYSTEM PARAMETERS (2)

ORBIT ALTITUDE:	200 ±30 KM	
FREQUENCY AGILITY:	3 RF'S PER BURST	
BURST; RATE:	227 Hz	
DUTY:	.4	
DUAL MODE:	PRINCIPLE (REAL APERTURE)	SECONDARY (DOPPLER)
TRANSMITTER:	3410 Hz	6820 Hz
PEAK POWER:	8 KW	8 KW
AVERAGE POWER:	75 WATTS	150 WATTS
RECEIVERS (185):		
NOISE FIGURES:	10 DB (MAX)	10 DB (MAX)
	8 DB (TYPICAL)	8 DB (TYPICAL)

SYSTEM PARAMETERS (3)

COVERAGE (H = 200 KM)

	MODE: PRINCIPLE	MODE: DOPPLER
SWATH WIDTH:	170 KM	170 KM
SWATH HEIGHT:	18 KM	12 KM
NO. OF INDEPENDENT SAMPLES:	200	200
DATA (SPACE); PRECISION:	5 BITS I,Q	5 BITS I,Q
RATE:	90 MB/S	120 MB/S

BURST TIMING
PRINCIPLE MODE

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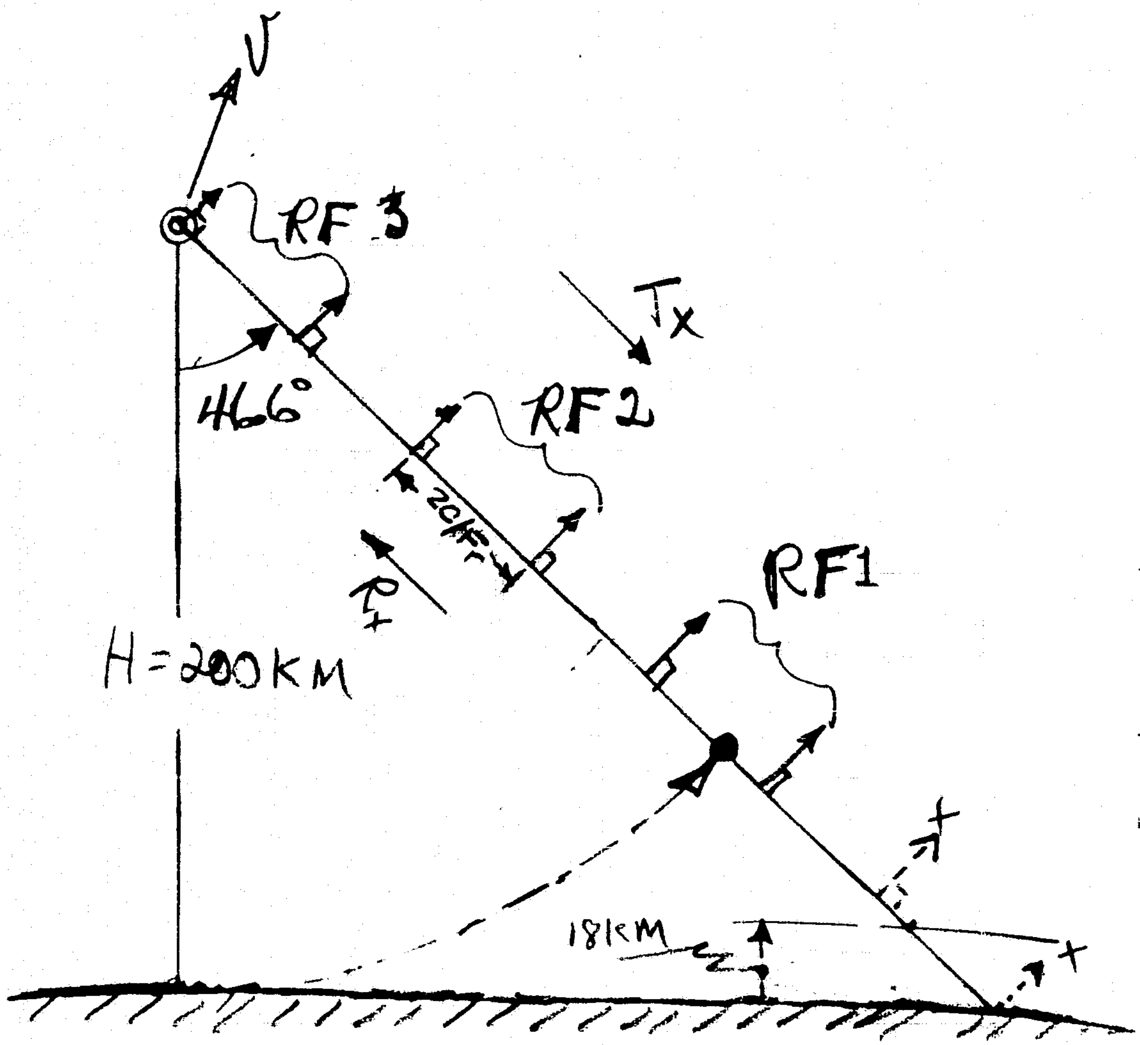

BURST TIMING

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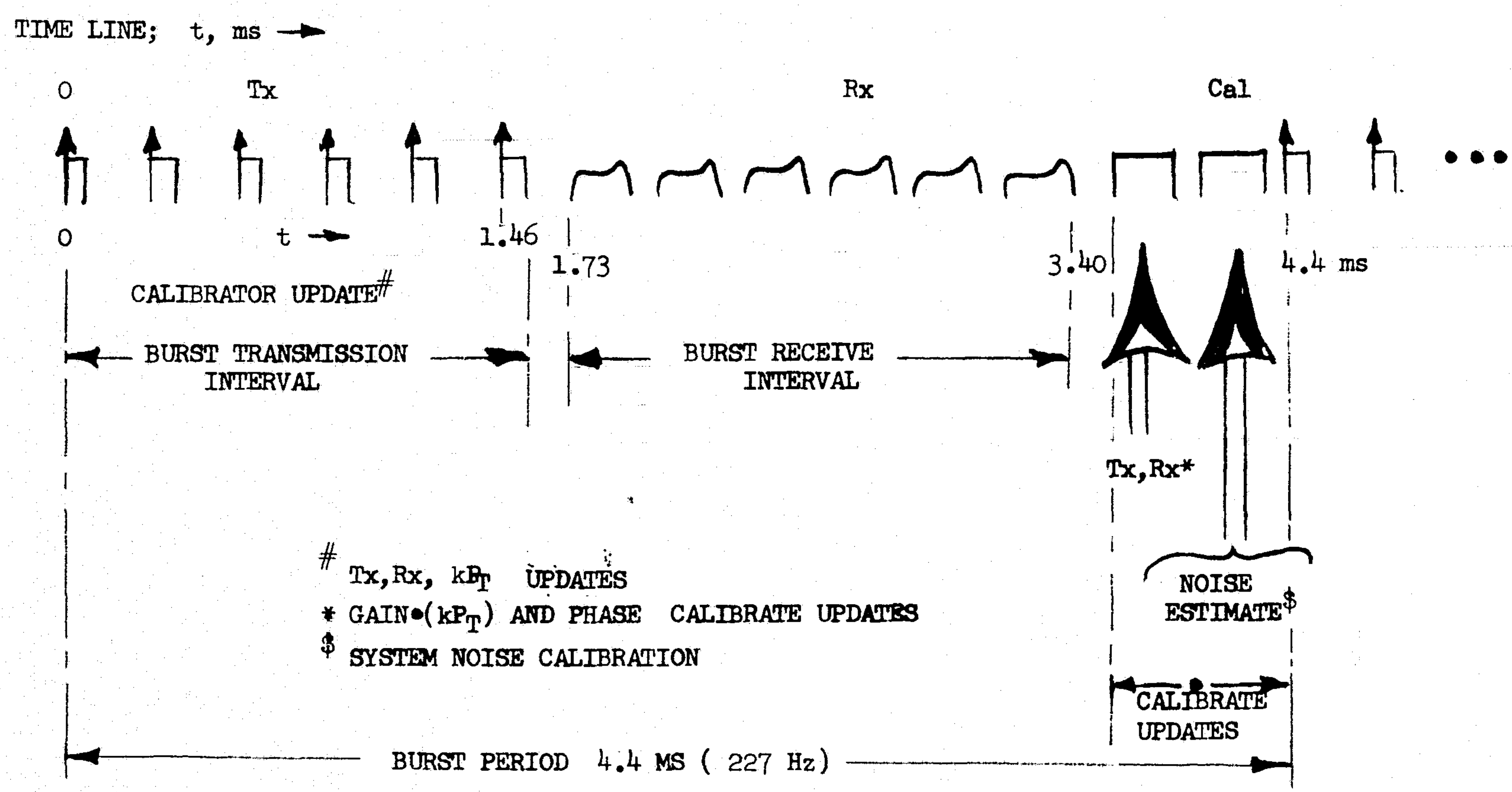
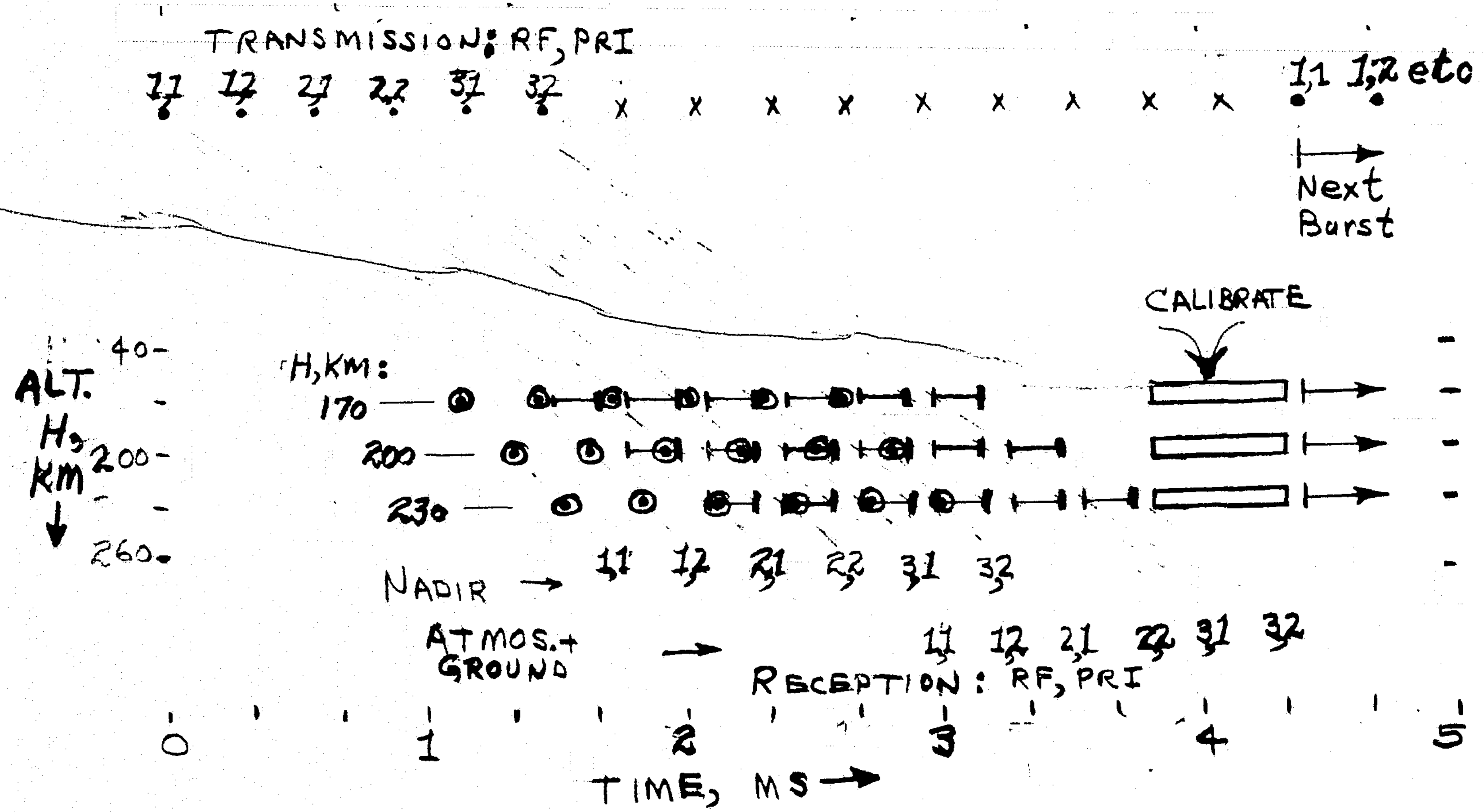


SENSITIVITY TO ORBITAL VARIATION



- **PRF: 3410 Hz (FIXED)**

ELEVATION PATTERN/RESOLUTION
SURFACE CLUTTER/SECOND GO-AROUND
DOPPLER MODE

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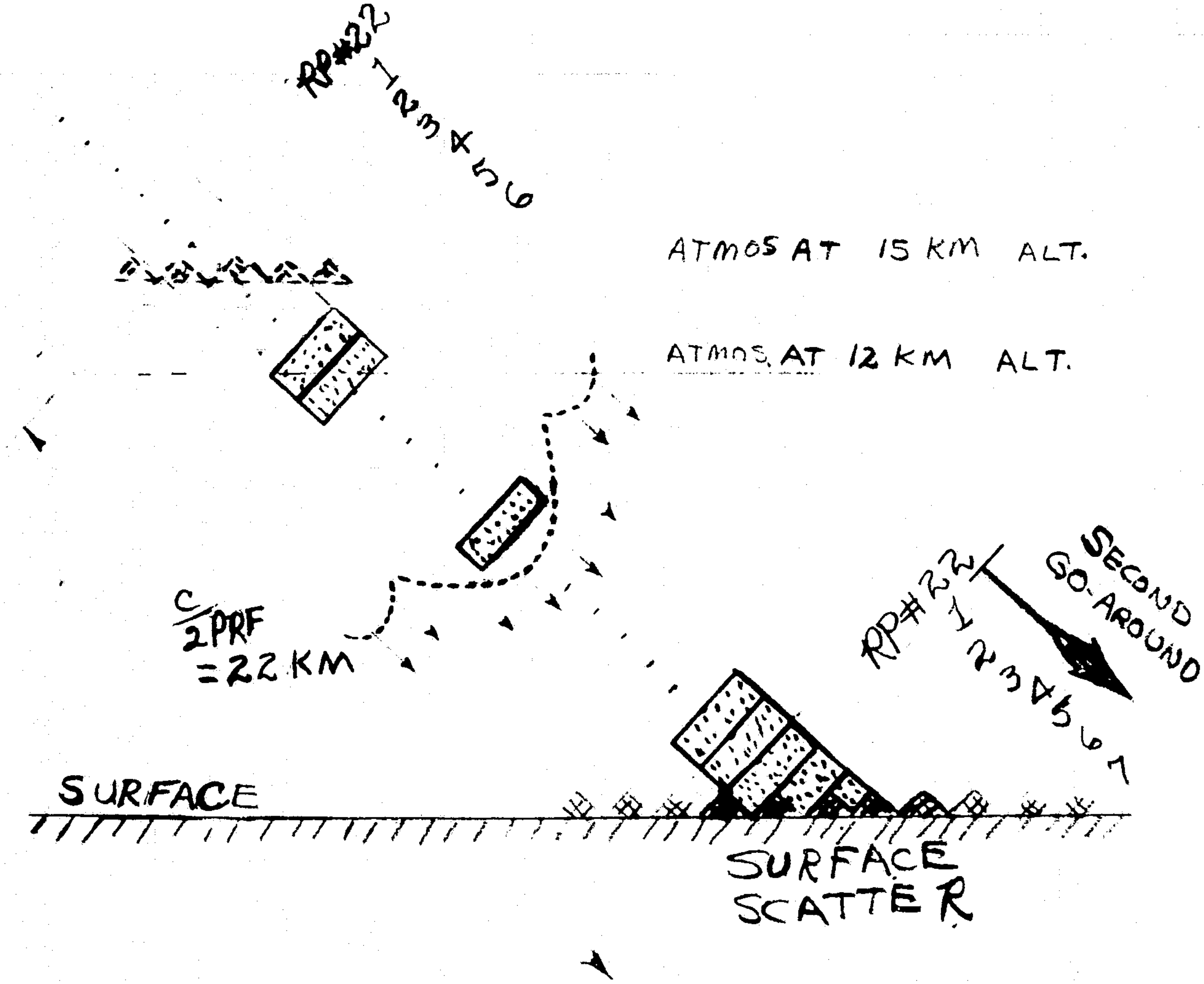

DATA RATES - DOPPLER MODE

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- PER CHANNEL: 150K COMPLEX WORDS/SEC. INSTANTANEOUS.
- AFTER 10/1 MULTIPLEXING: 1.5M REAL WORDS/SEC.
- AFTER 4/1 MULTIPLEXING: 6M REAL WORDS/SEC.
- AFTER A/D CONVERSION: 36M BITS/SEC.
- AFTER BIT SELECTION: 30M BITS/SEC.
- RATE INTO BUFFER/FORMATTER: 300 M BITS/SEC.
- RATE INTO RECORDER: 120 M BITS/SEC.

MAJOR SYSTEM DESIGN DECISIONS

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- GROUND PROCESSING
- AGC FOR FIXED P_T . GAIN PRODUCT
- CALIBRATION/AGC APPROACH
- BURST MODE
- X-BAND
- TIME MULTIPLEXING
- NO RF AMPLIFICATION
- ANTENNA ATTITUDE STABILIZATION

ADVANTAGES OF GROUND PROCESSING

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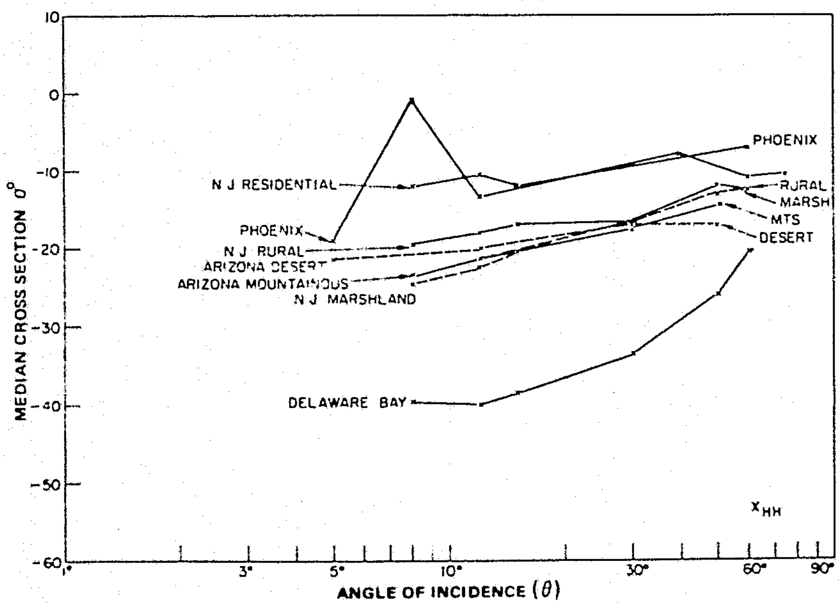
- MAINTAINS DATA INTEGRITY
- LESS COSTLY THAN SPACE PROCESSING
- PROVIDES FLEXIBILITY - COMPARISON OF ALTERNATIVE APPROACHES AND ALGORITHMS
- DATA RATES COMPATIBLE WITH RECORDER CAPABILITY
- SAVES POWER (1 K WATT)

MEDIAN TERRAIN σ_0 AT X-BAND



ATMOSPHERIC RETURN RELATIVE TO GROUND RETURN

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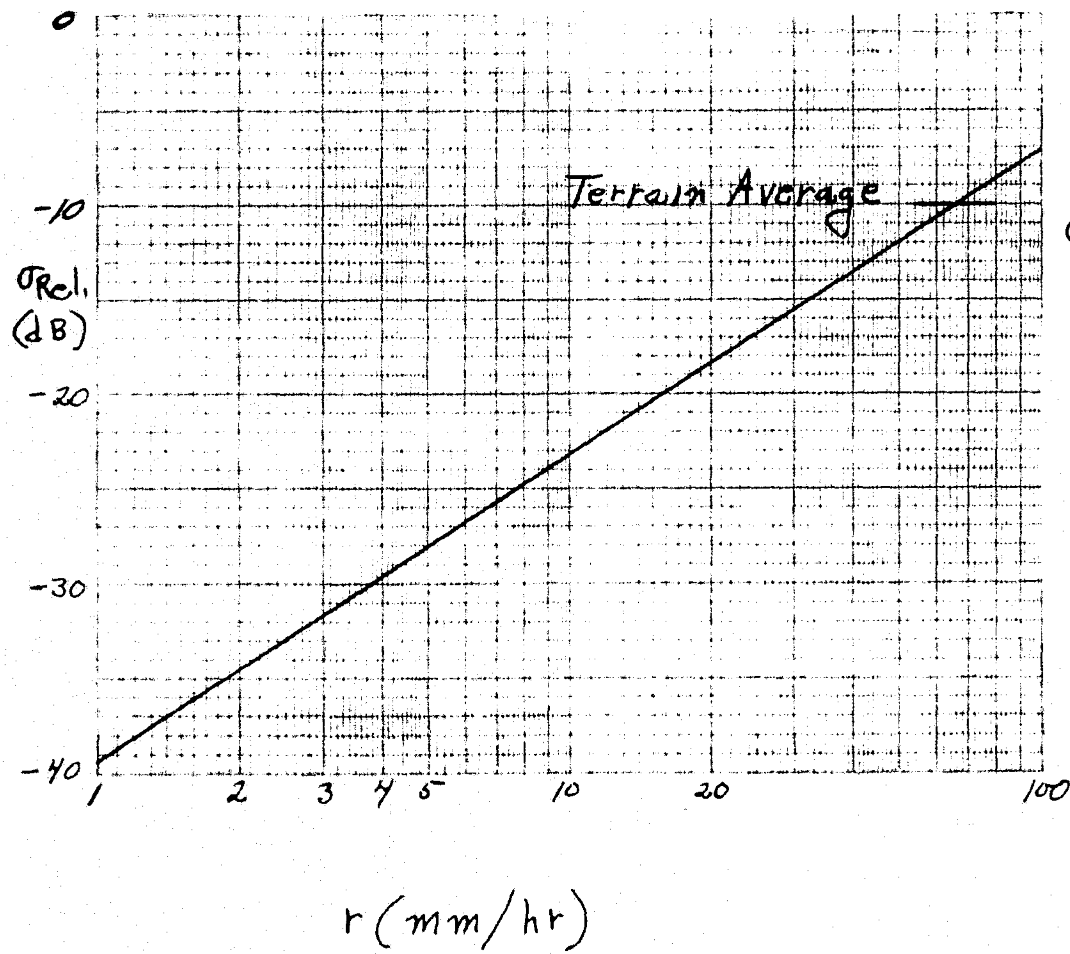

$$\sigma_{Rel.} = \frac{2 d_r 10^{-18} \pi^5 (.93) 200 r^{1.6}}{\lambda^4}$$

$\lambda = .03M, \quad d_r = 10^3 M.$

DYNAMIC RANGE REQUIREMENTS

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REFLECTIVITY (RELATIVE TO TERRAIN)

-8 DB 92% OF TERRAIN RETURN BELOW THIS LEVEL

-14 DB 35 MM/HR EXTENSIVE, OR 150 MM/HR. OVER 10%

MOST SIGNIFICANT
5 BITS

LEAST SIGNIFICANT
5 BITS

(OF 6 BIT A/D)

-39 DB 1 MM/HR EXTENSIVE

-43 DB 1 MM/HR OVER 25%

-49 DB 1 MM/HR OVER 10%

AGC CONCLUSION

- AGC FOR FIXED SYSTEM GAIN (FIXED P_T . GAIN PRODUCT)
- USE 6 BIT A/D CONVERTER
- RECORD LEAST SIGNIFICANT 5 BITS FOR ATMOSPHERIC RETURN
- RECORD MOST SIGNIFICANT 5 BITS FOR GROUND RETURN

CALIBRATE/AGC APPROACH

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- o CALIBRATION REQUIREMENT: SET P_T . GAIN PRODUCT TO SELECTED VALUE
  - DERIVE PILOT SIGNAL PROPORTIONAL TO TRANSMITTED POWER P_T
  - INJECT PILOT SIGNALS INTO RECEIVERS FOR CALIBRATION
  - AGC EACH RECEIVER FOR SELECTED OUTPUT DURING CALIBRATION

AND

- o USE INJECTED PILOT SIGNALS TO SATISFY REQUIREMENT FOR PHASE CALIBRATION

BURST MODE

- o SIMPLER THAN CONTINUOUS OPERATION.
  - NO TRANSMITTER ECLOPSING IN ATMOSPHERE
  - PRF CAN BE FIXED
- o REQUIRES LESS TRANSMITTED POWER (DOPPLER MODE)
- o PROVIDES REQUIRED NUMBER OF INDEPENDENT LOOKS
- o ALLOWS GREATER FLEXIBILITY IN CHOICE OF PRF FOR DOPPLER AMBIGUITY/ ATMOSPHERE AMBIGUITY TRADE-OFF.

- LOWER FREQUENCY SACRIFICES RESOLUTION AND SENSITIVITY.
- HIGHER FREQUENCY CARRIES MAJOR COST PENALTY.

FREQUENCY MULTIPLEX ALIASING

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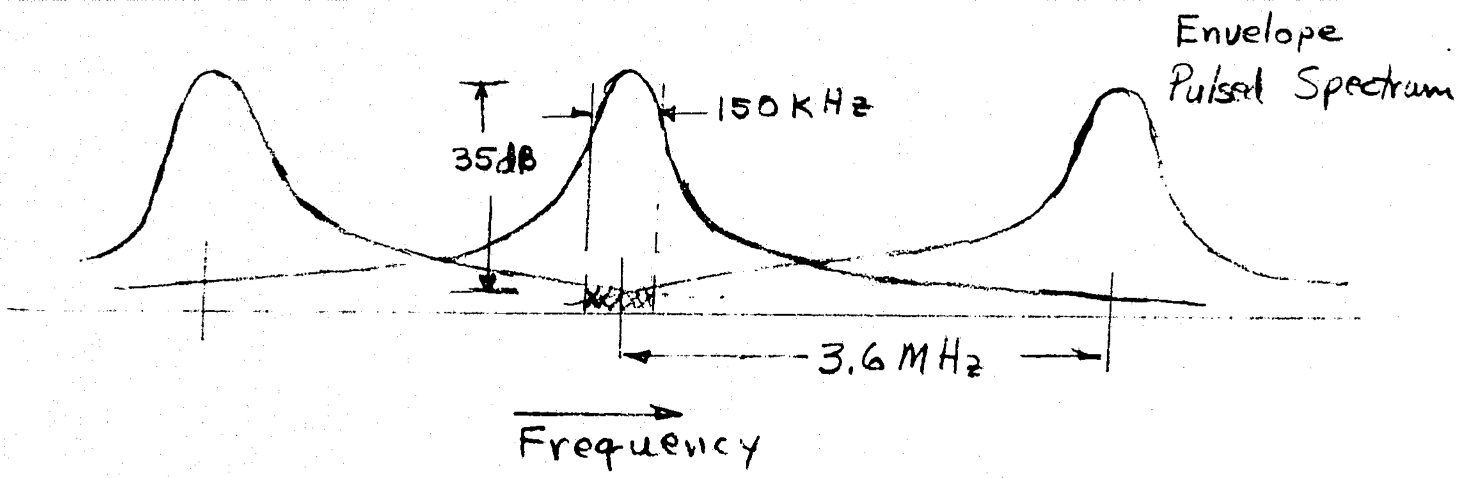

- ALLOWABLE CROSS-TALK POWER ≤ -35 DB
- FREQUENCY SEPARATION IMPLIES:

  A) HIGH DATA RATE (~ 24×NYQUIST)

  OR

  B) DE-MUX TO INDIVIDUAL I/Q CHANNELS

TIME MULTIPLEXING

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- o FREQUENCY MULTIPLEXING REQUIRES LARGE FREQUENCY SEPARATION TO REDUCE CROSS-TALK CAUSED BY ALIASING.
- o SEPARATION LEADS TO LARGE INCREASE IN DATA RATE.
- o CONCLUSION - USE TIME MULTIPLEXING.

ANTENNA ATTITUDE STABILIZATION

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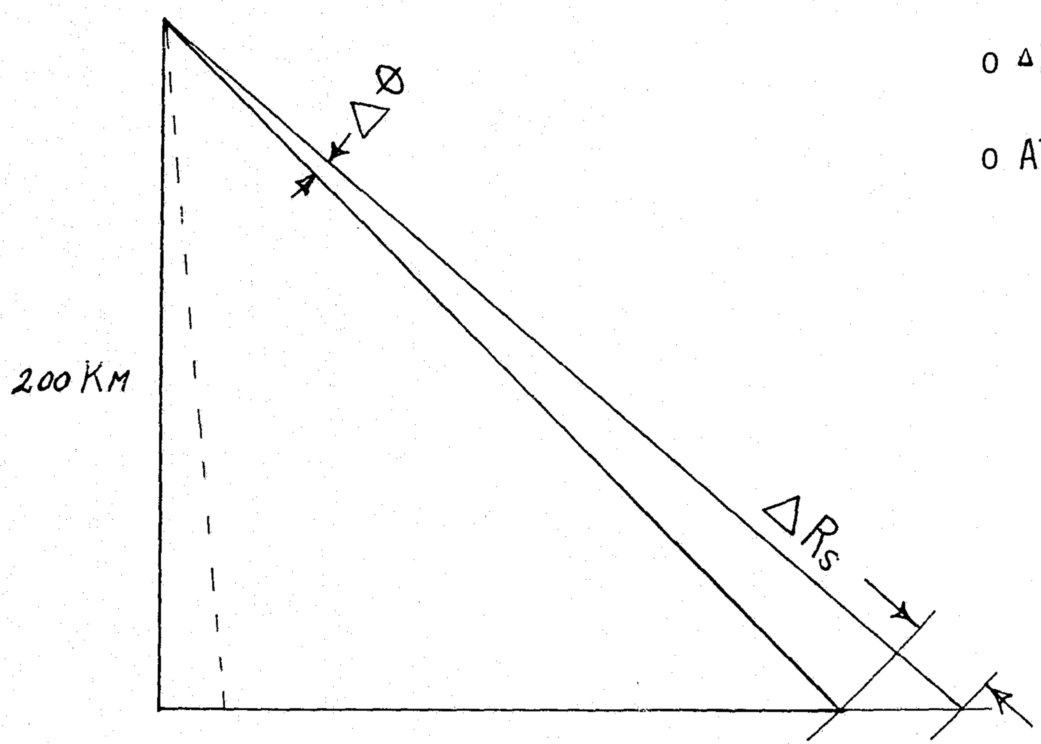
- DEVIATION OF ANTENNA AXIS FROM VERTICAL CAUSES GROUND CLUTTER CONTAMINATION OF ATMOSPHERE RETURN.



- ΔR_s = 5 KM/DEGREE
- ATTITUDE STABILIZATION APPROACH:
  SENSE ΔR_s DIRECTLY, AND CONTROL $\Delta\theta$ TO NULL ΔR_s.

RF AMPLIFICATION CHOICE

	RF AMPLIFIERS	NO RF AMPLIFIERS
ADVANTAGES	LOWER NOISE FIGURE (4 dB) REQUIRES LESS TRANSMITTER POWER.	SIMPLER, LIGHTER, CHEAPER
DISADVANTAGES	GREATER WEIGHT, COMPLEXITY, COST.	HIGHER NOISE FIGURE (8 dB). REQUIRES 4 dB MORE TRANSMITTER POWER.

CHOICE: NO RF AMPLIFICATION.

RECEIVER SYSTEM APPROACH TRADE-OFFS

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		BEAM FORMATION	
		AT I.F. OR AT R.F.	AFTER A/D CONVERSION
MULTIPLEXING	TIME	LACK OF FLEXIBILITY IN GAIN AND PHASE BALANCE AND ARRAY WEIGHTING	FLEXIBLE. MODERATE BANDWIDTH (278 M BITS/SEC) BEFORE BUFFERING.
	FREQUENCY		FLEXIBLE. EXCESSIVE BANDWIDTH (6.7 G BITS/SEC.) REQUIRED TO REDUCE CROSSTALK.

TOPICS:

- PARAMETERS
- CALIBRATION ERROR BUDGET
- RF LOSS BUDGET
- SIGNAL-TO-NOISE RATIO VS. RAINFALL RATE
- SEVERE STORM, TOTAL NOISE BUDGET
- ESTIMATION BIAS
- DOPPLER MODE HEIGHT LIMITS
- MEASUREMENT ACCURACY

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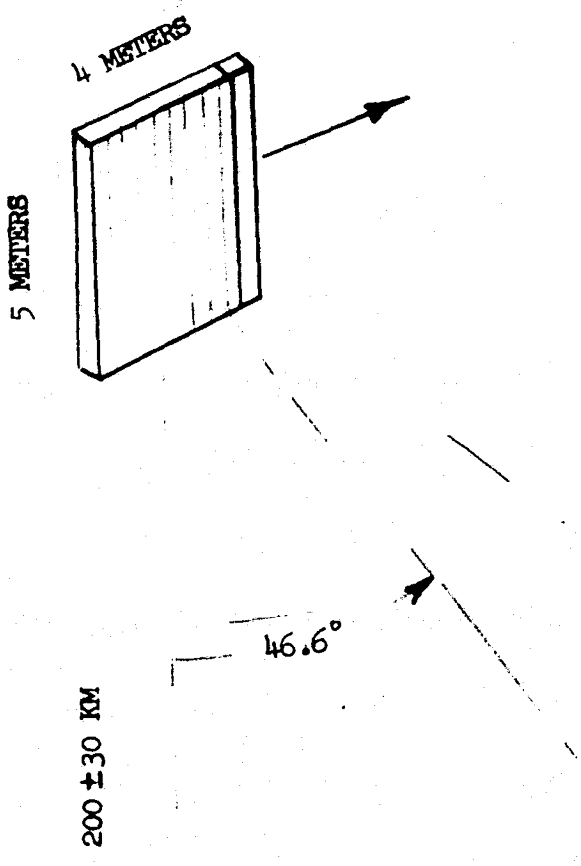
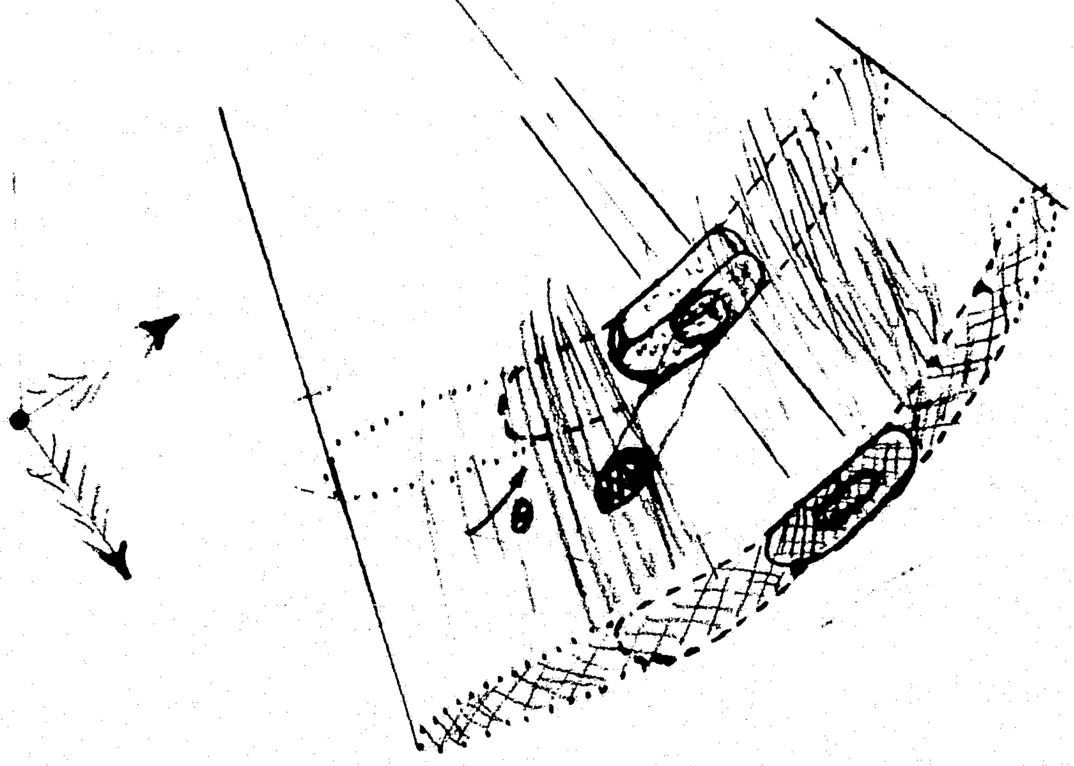
PERFORMANCE

GEOMETRY



SEVERE STORM MODEL:

RESOLUTION CELL EMBEDDED IN UNIFORM RAINFALL AT 4MM/HR, SURROUNDED BY HEAVY RAINFALL AT 20 MM/HR WITH LAND SURFACE CLUTTER REFLECTIVITIES OF σ_o=0 dB (FIRST SIDE LOBE) AND -10 dB RMS



PERFORMANCE PARAMETERS (1)

NOMINAL ORBIT ALTITUDE:	200 KM
PRINCIPLE MODE:	REAL APERTURE
SWATH: WIDTH =	170 KM
HEIGHT =	18 KM
SPATIAL RESOLUTION:	3 x 3 x 1.5 KM
NO. OF INDEPENDENT SAMPLES:	200
CALIBRATION ACCURACY*:	1.2 DB, 80% CONFIDENCE
STORM MODEL:	SEVERE, 20 MM/HR OVER 30 KM DISTANCE
CELL-OF-INTEREST:	4 MM/HR
MEASUREMENT ACCURACY*:	1.6 DB, 80% CONFIDENCE

---

* BIAS CONTRIBUTION CONSIDERED SEPARATELY

PERFORMANCE PARAMETERS (2)

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RECEIVERS:	
NOISE FIGURES:	10 DB MAXIMUM; 8 DB TYPICAL
INTERCHANNEL ISOLATION:	35 DB NET RMS
ANTENNAS (TRANSMIT & RECEIVE):	
APERTURE EFFICIENCY:	80%, MINIMUM
LOSSES:	1.2 DB OHMIC, MAXIMUM
ELEVATION SIDELOBES:	-25 DB PEAK
GRATING LOBES:	-25 DB PEAK
PRINCIPLE MODE BEAMS:	
AZIMUTH SIDELOBES:	-35 DB RMS, MAXIMUM
GRATING LOBES:	-25 DB PEAK, -35 DB RMS
OFF-AXIS LOBES:	-65 DB (TWO-WAY), RMS

CALIBRATION ERROR BUDGET

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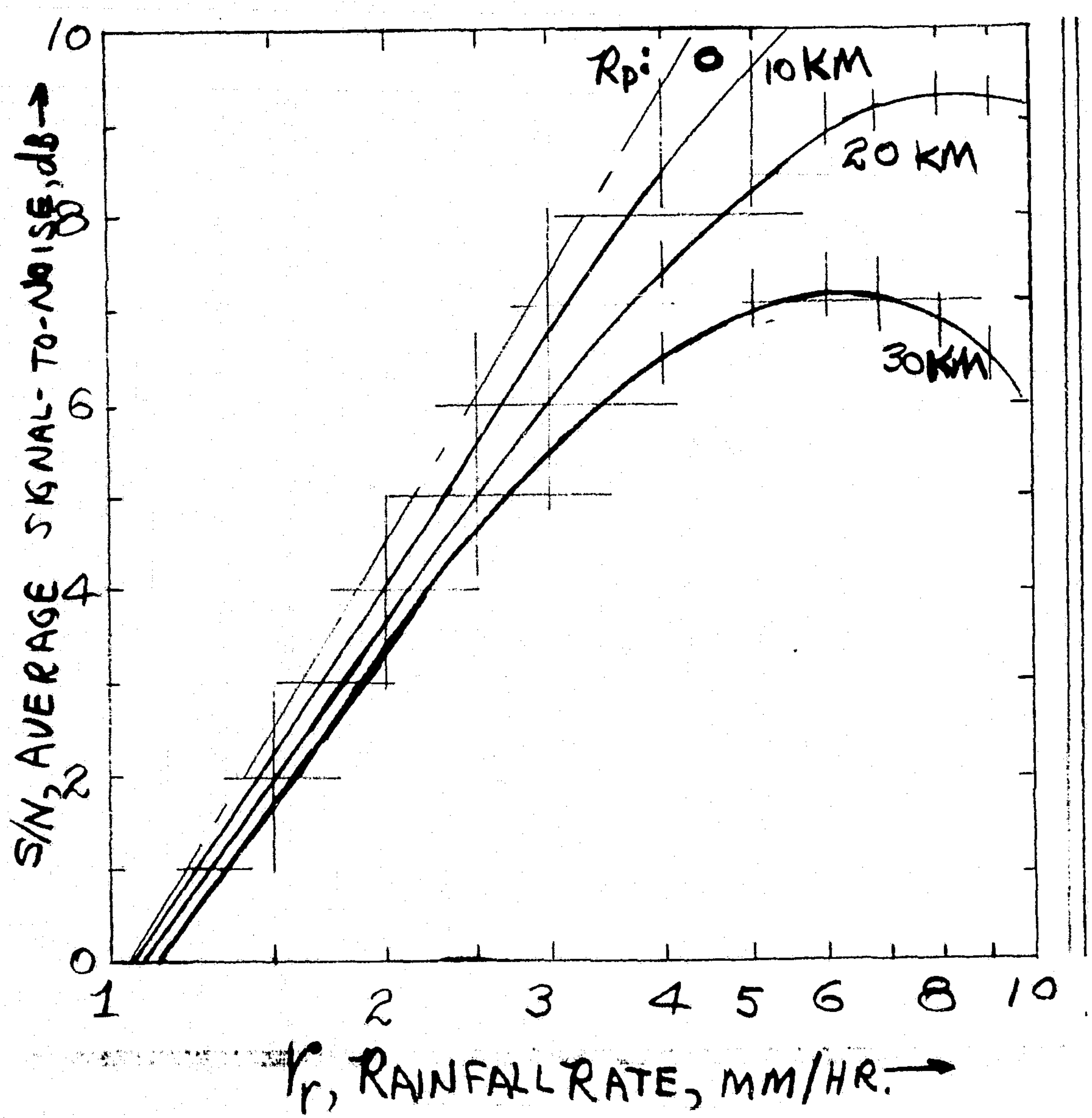
PARAMETER	COMPONENT* FIXED	TEMPORAL
TRANSMITTER/RECEIVER	.3 DB	.3 DB
ANTENNA FACTORS, RSS	.6	.3
RF PLUMBING	.2	.1
SYSTEM NOISE ESTIMATE	-	.05
RSS	.70 DB	.44 DB

* RMS (1 SIGMA) ERRORS, FIXED ERRORS ARE ATTRIBUTED TO SAMPLE (ONE) FROM ENSEMBLE OF SYSTEMS

MRF RF LOSS BUDGET

RECEIVER NOISE FIGURE, MAX	10 DB
ANTENNA OHMIC LOSSES (TWO-WAY)	2 DB
RF COUPLING LOSSES, MAX	
TRANSMIT	1.0 DB
RECEIVE	1.8 DB
PROPAGATION LOSSES, TYPICAL	.3 DB
A/D CONVERTER & MISC.	.9 DB
TOTAL	16.0 DB

SINGLE PULSE SIGNAL-TO-NOISE RATIO
VS. RAINFALL RATE



$$\frac{S}{N} = \frac{P_T \lambda^2 G_T G_R (\Omega_R R^2 d_r) \eta_r}{(4\pi)^3 R^4 \quad KTB} \cdot \frac{L_T L_R L_P}{F}$$

WHERE:

$$G_R \Omega_R = \frac{4\pi \rho_R}{\Omega_R} \Omega_R$$

$\Omega_R R^2 d_r \eta_r$: RADAR CROSS-SECTION OF ISOTROPIC RAIN BACKSCATTER

$\eta_r = \frac{\pi^5 |K|^2 \cdot 10^{-18}}{\lambda^4} Z_e$; $Z_e \rightarrow 200 r_r^{1.6}$, r_r : RAIN RATE, MM/HR

$$\bullet \quad \frac{S}{N} = P_T \cdot \left(\frac{\lambda}{4\pi R} \right)^2 \cdot \frac{d_r \eta_r}{KTB} \cdot \frac{\rho_R G_T L_T L_R L_P}{F} = \boxed{8.4 \text{ dB}}$$

$P_T = 8$ KW; $d_r \eta_r = -32$ dBZ ($d_r = 1$ KM); $B = 200$ KHz

$G_T = 29$ dB; $\rho_R = .86$; $\frac{L_T L_R L_P}{F} = -16$ dB

TOTAL NOISE BUDGET
SEVERE STORM MODEL

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SIGNAL: -32 DBZ/KM (4MM/HR) OVER CELL-OF-INTEREST

RAIN CLUTTER: -21 DBZ/KM (20 MM/HR) OUTSIDE SIGNAL CELL

SURFACE CLUTTER: (RELATIVE TO AZIMUTH SECTOR OF SIGNAL CELL):

INSIDE: σ_0 = 0 DB

OUTSIDE: $\overline{\sigma_0}$ = -10 DB

SIGNAL-TO:

THERMAL + A/D CONV. NOISE	$\geq$ 9 DB
SURFACE CLUTTER	$\geq$17 DB
RAIN CLUTTER	$\geq$ 9 DB
TOTAL NOISE	$\geq$5.6 DB
CLUTTER	$\geq$8.5 DB

CLUTTER MODEL FOR SEVERE STORM

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CLUTTER CONTRIBUTION	ANTENNA PATTERN REDUCTION FACTOR (DB)	# CELLS (DB)	AVERAGE DBZ	CLUTTER CONTRIBUTION (DBZ)
ELEVATION M.L., AZIMUTH S.L. (1 WAY)				
RMS	-35	+10	-21(20MM/HR)	-46
GRATING LOBES	-25	+ 3	-21	-43
AZIMUTH M.L., ELEVATION S.L. (2 WAY)				
RMS	-60	+10	-21	-71
GRATING LOBES	-50	0	0 (GROUND CELL)	-50
AZIMUTH S.L., ELEVATION S.L.				
RMS	-65	+20	-21	-66
		+20	-10 (GROUND CELLS)	-55

CLUTTER CALCULATION FOR SEVERE STORM

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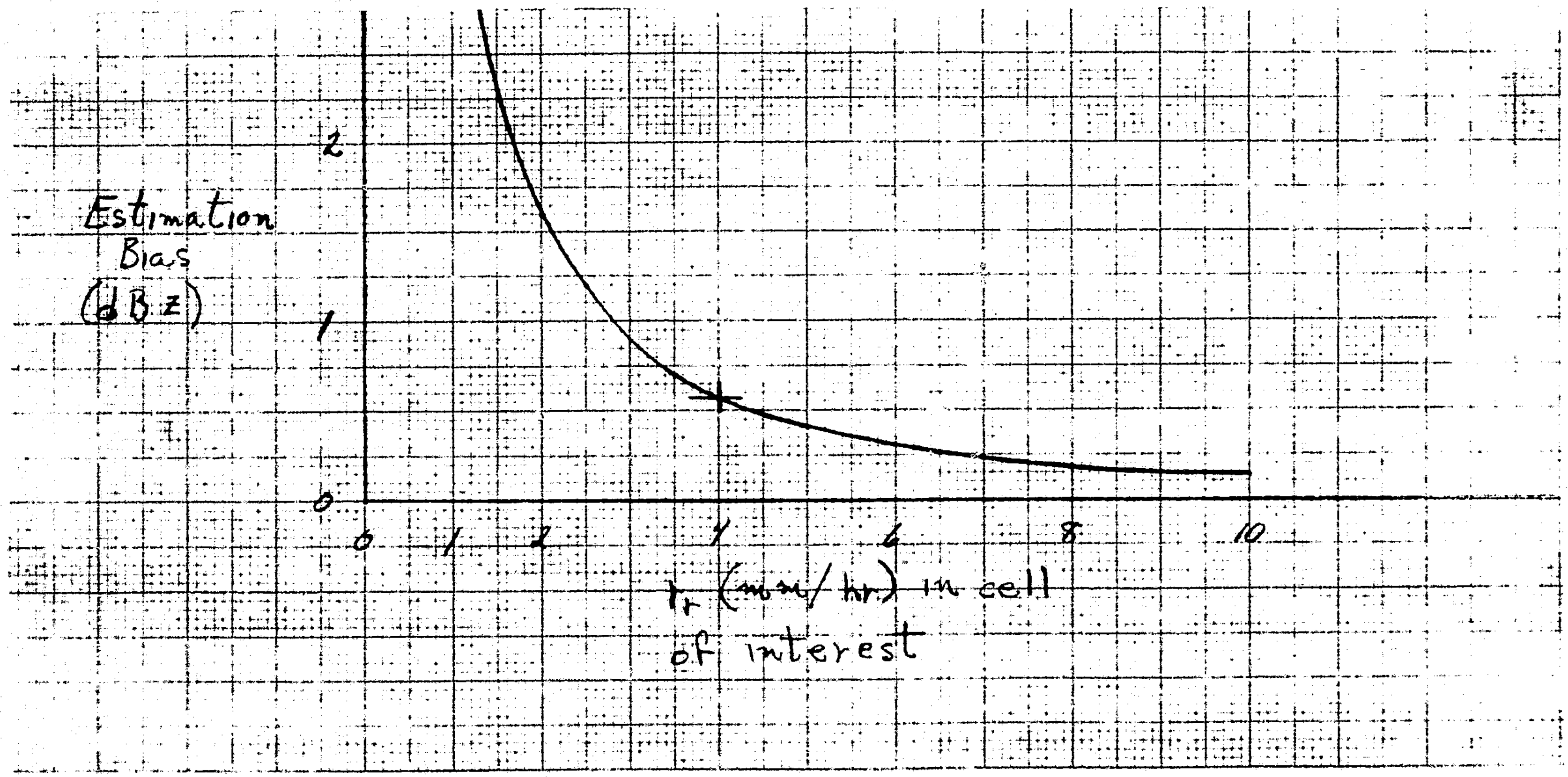
GROUND CLUTTER CONTRIBUTION: - 49 dBz

RAIN CLUTTER CONTRIBUTION: - 41 dBz

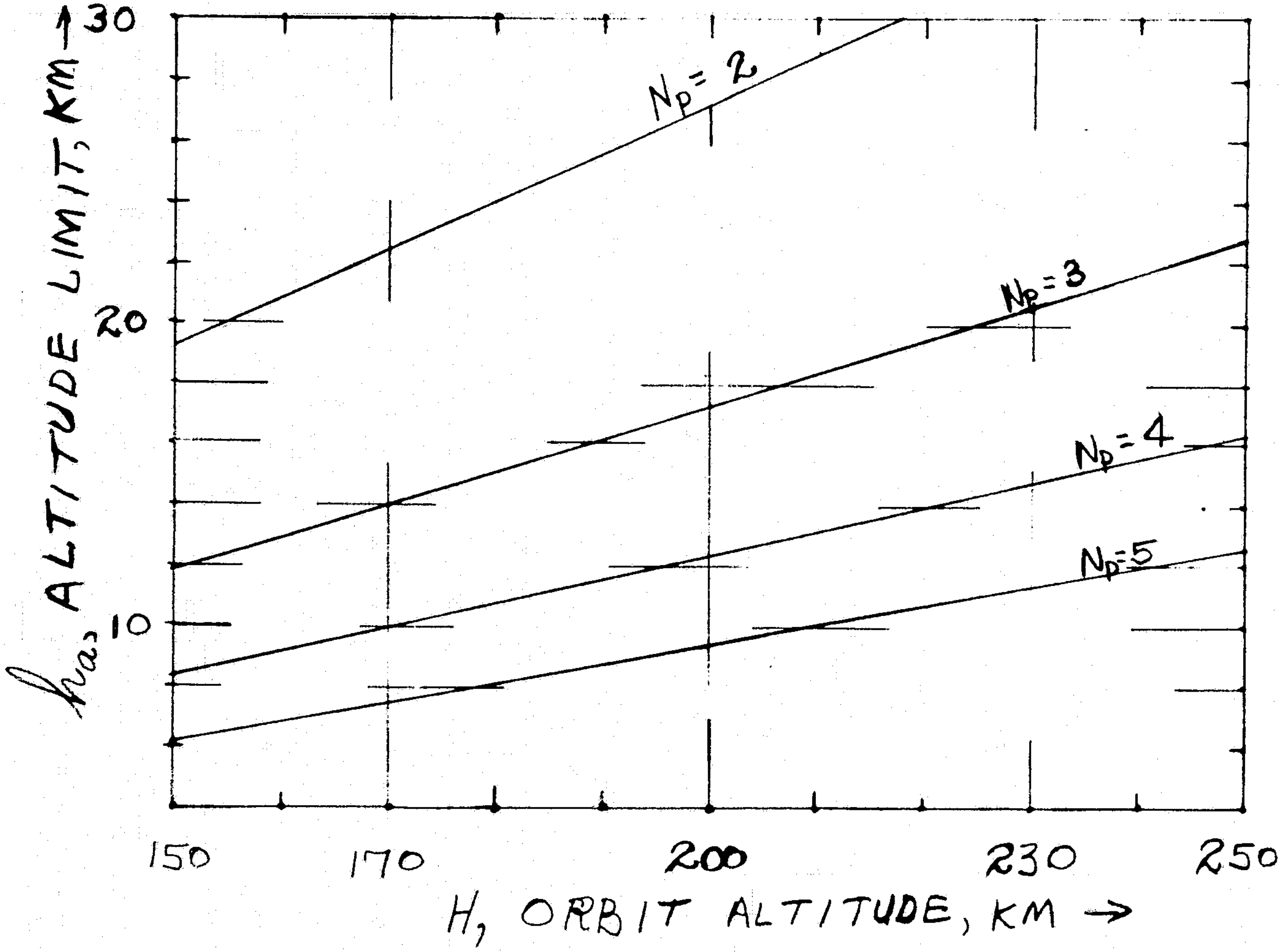
TOTAL CLUTTER CONTRIBUTION: - 40.5 dBz (1.2 mm/hr)

AT 4 mm/hr, S/C = 8.5 dB

o CAUSED BY UNCOMPENSATED CLUTTER



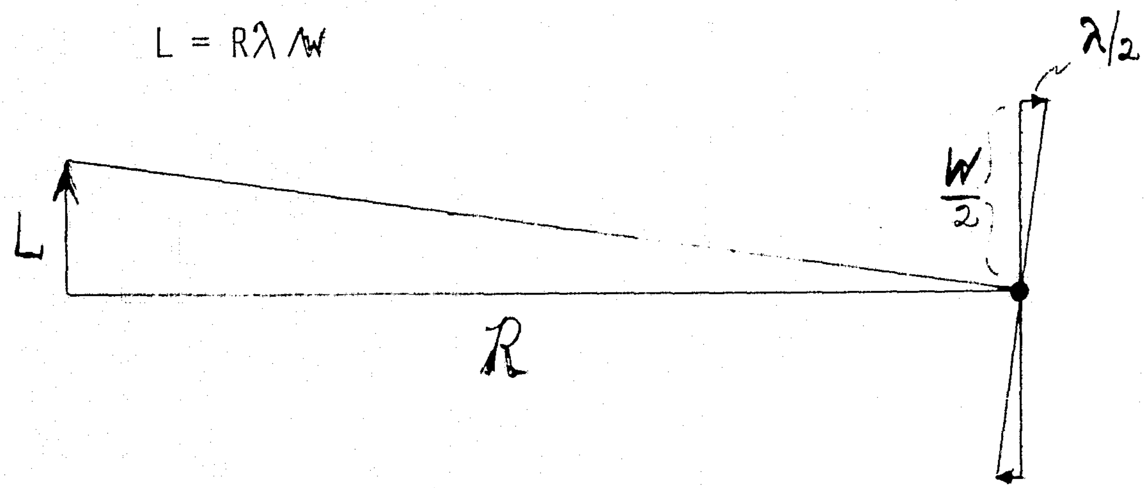
DOPPLER MODE
ATMOSPHERIC HEIGHT LIMITS
ORBIT ALTITUDE: 200 ±30 KM



N_p = PULSES PROCESSED PER RF INTRA-BURST PERIOD

NUMBER OF INDEPENDENT LOOKS M

- M = 200 FOR ORBIT DISTANCE D = 1.5 KM AND:
  RESOLUTION W = 3 KM, RANGE R = 300 KM
  λ = .03 M, DUTY FACTOR F = .4.
- $M = FD/L = FDW/R\lambda$
  WHERE L IS DECORRELATION DISTANCE:
  $L = R\lambda/W$



ASSUMPTIONS: NO FREQUENCY HOPPING, PRF OVERSAMPLING.

DOPPLER VS. AZIMUTH ANGLE

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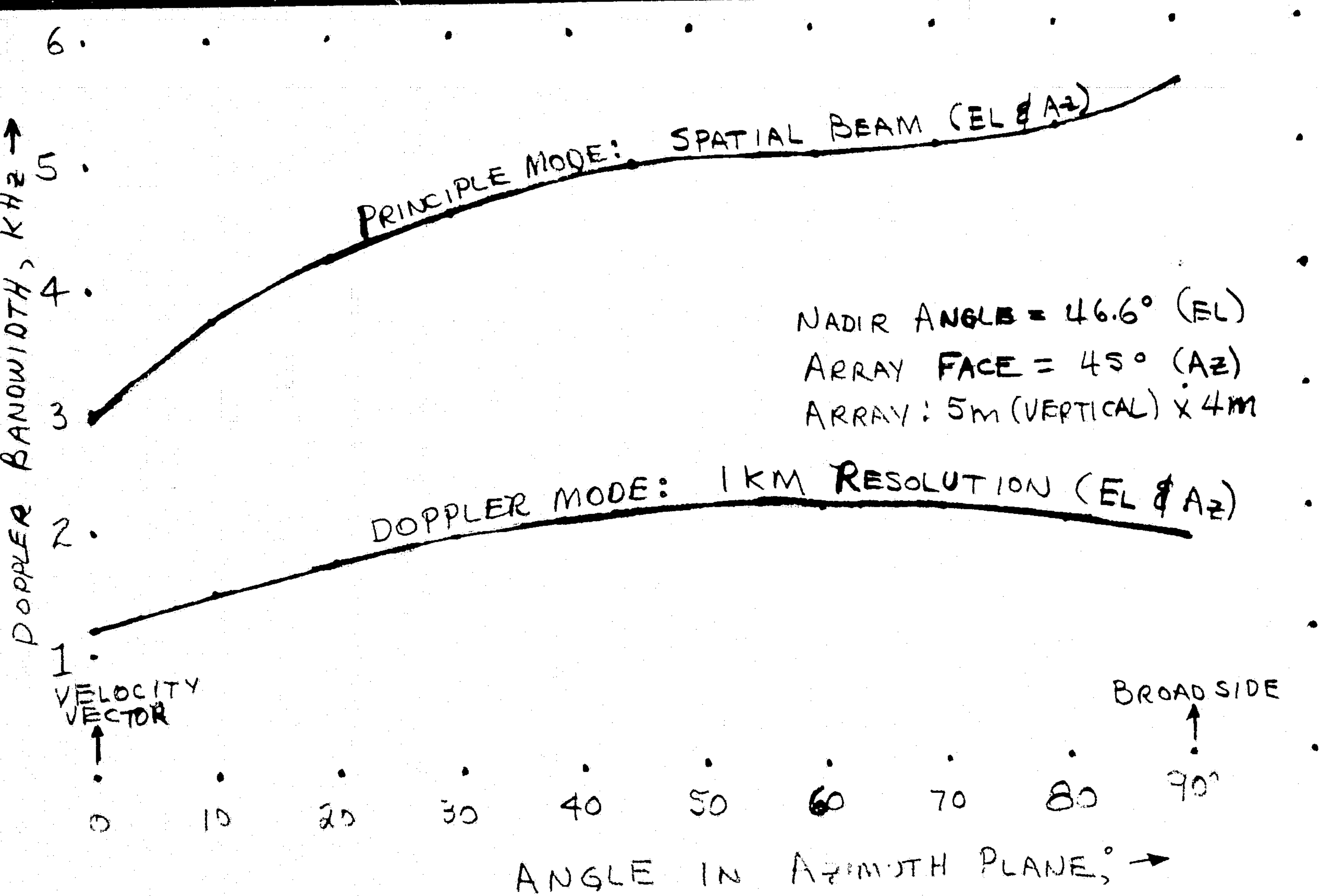

MEASUREMENT ACCURACY VS. S/N & INDEPENDENT SAMPLES

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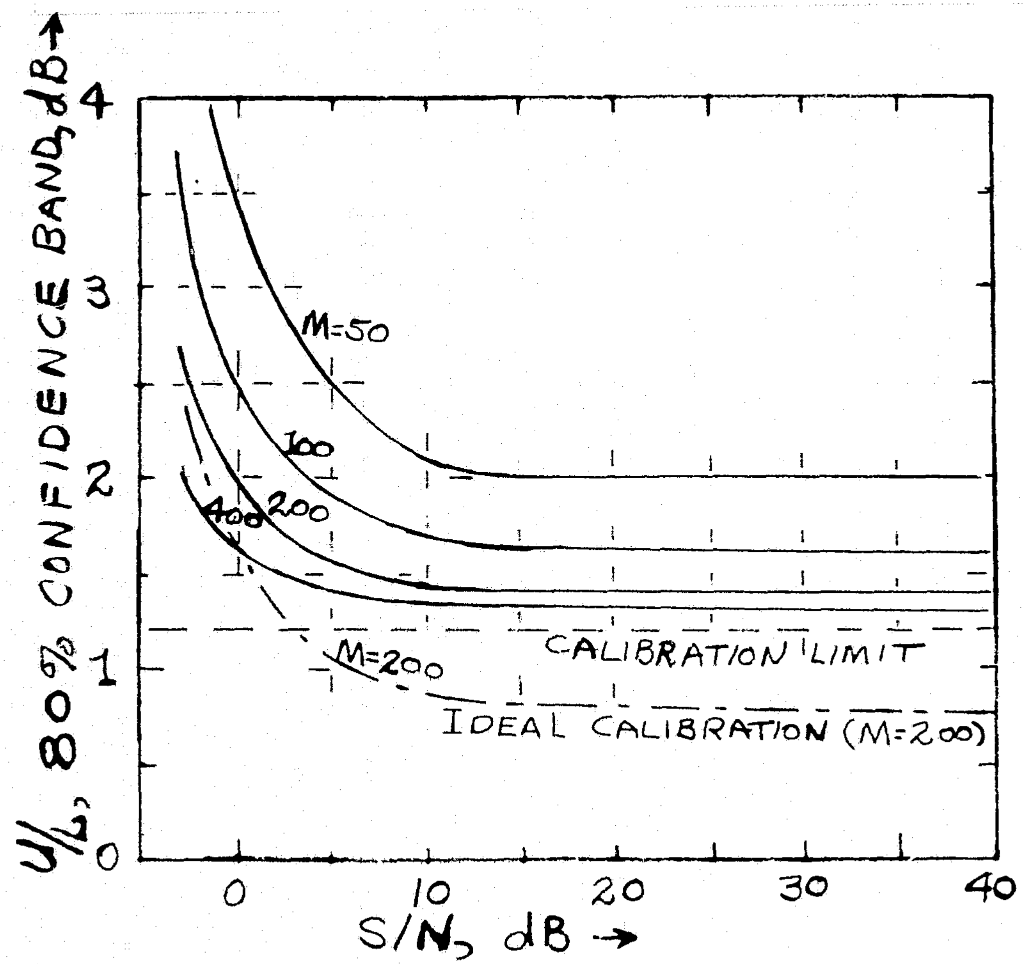

$$\frac{U}{L} = \frac{1 + X_\alpha \sigma_N}{1 - X_\alpha \sigma_N}$$

$X_\alpha = 1.282$ FOR α @ 80% CONFIDENCE LEVEL

$$\sigma_N^2 = \frac{(1 + N/S)^2}{M} + \sigma_c^2$$

σ_c^2 = VARIANCE IN CALIBRATION

OBSERVATIONS M VS. RAINFALL RATE

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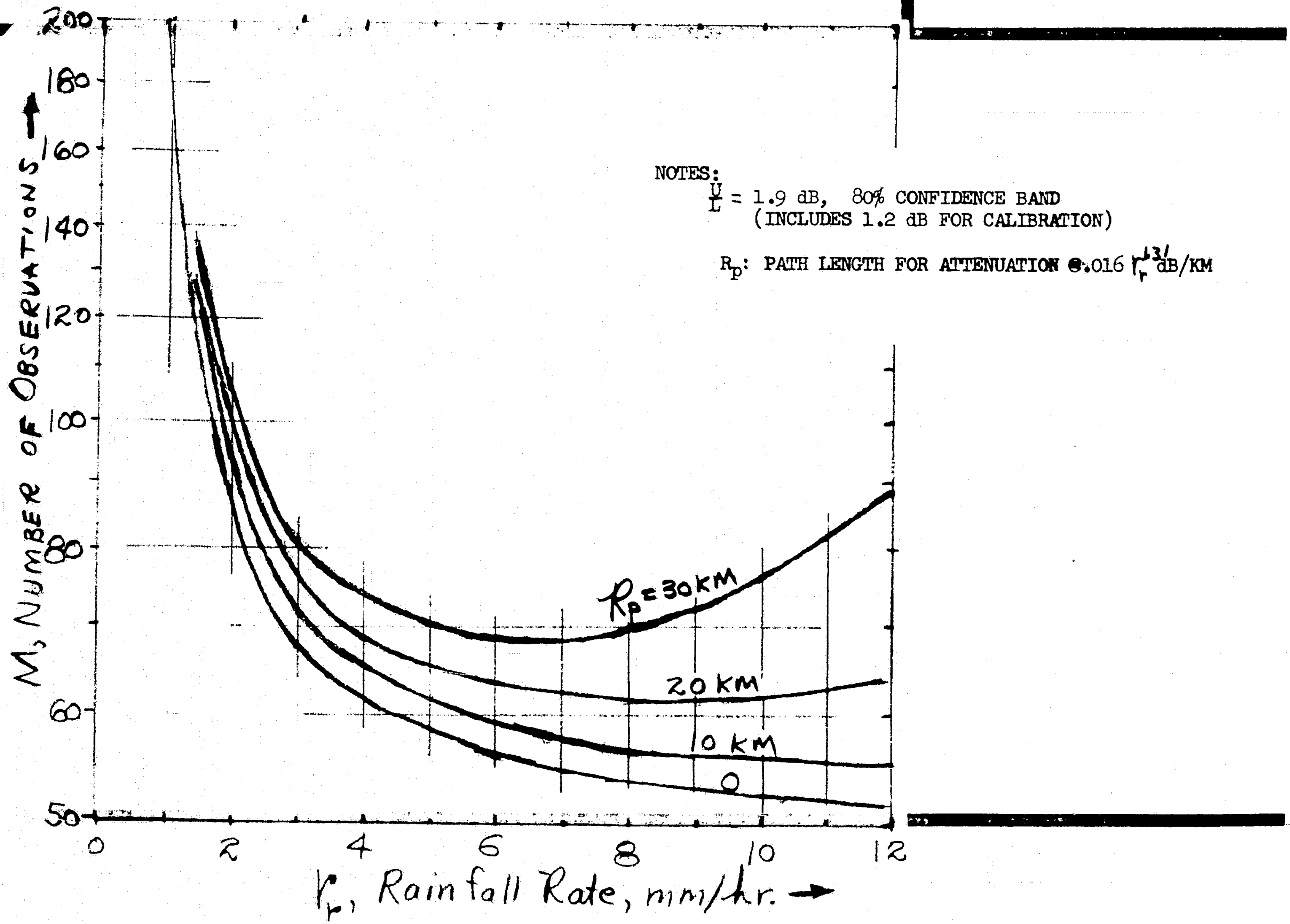

EFFECT OF PHASE ERRORS ON SIDELOBES

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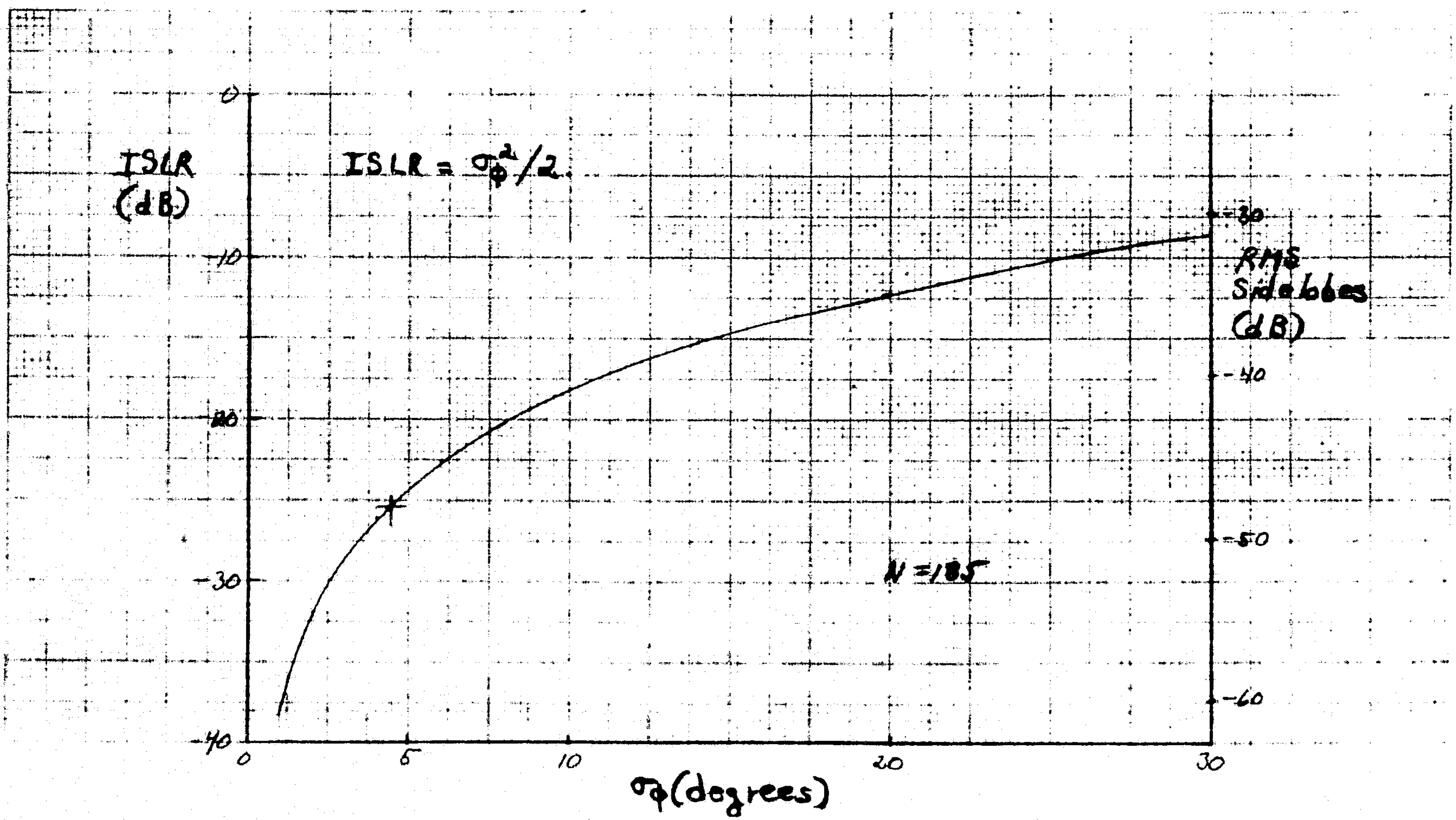
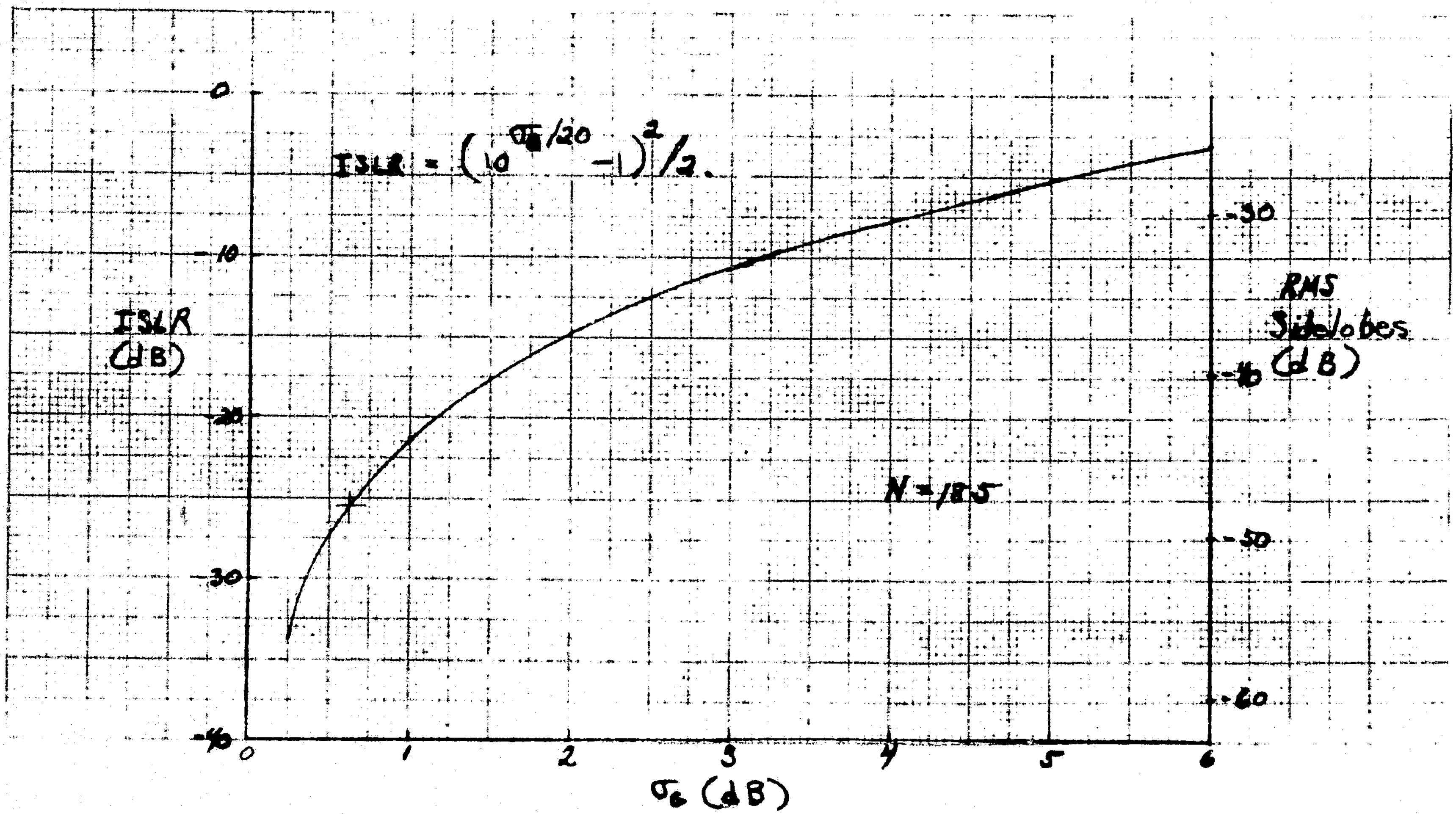


EFFECT OF GAIN ERRORS ON SIDELOBES



RELATIVE SENSITIVITIES VS. RF WAVELENGTH

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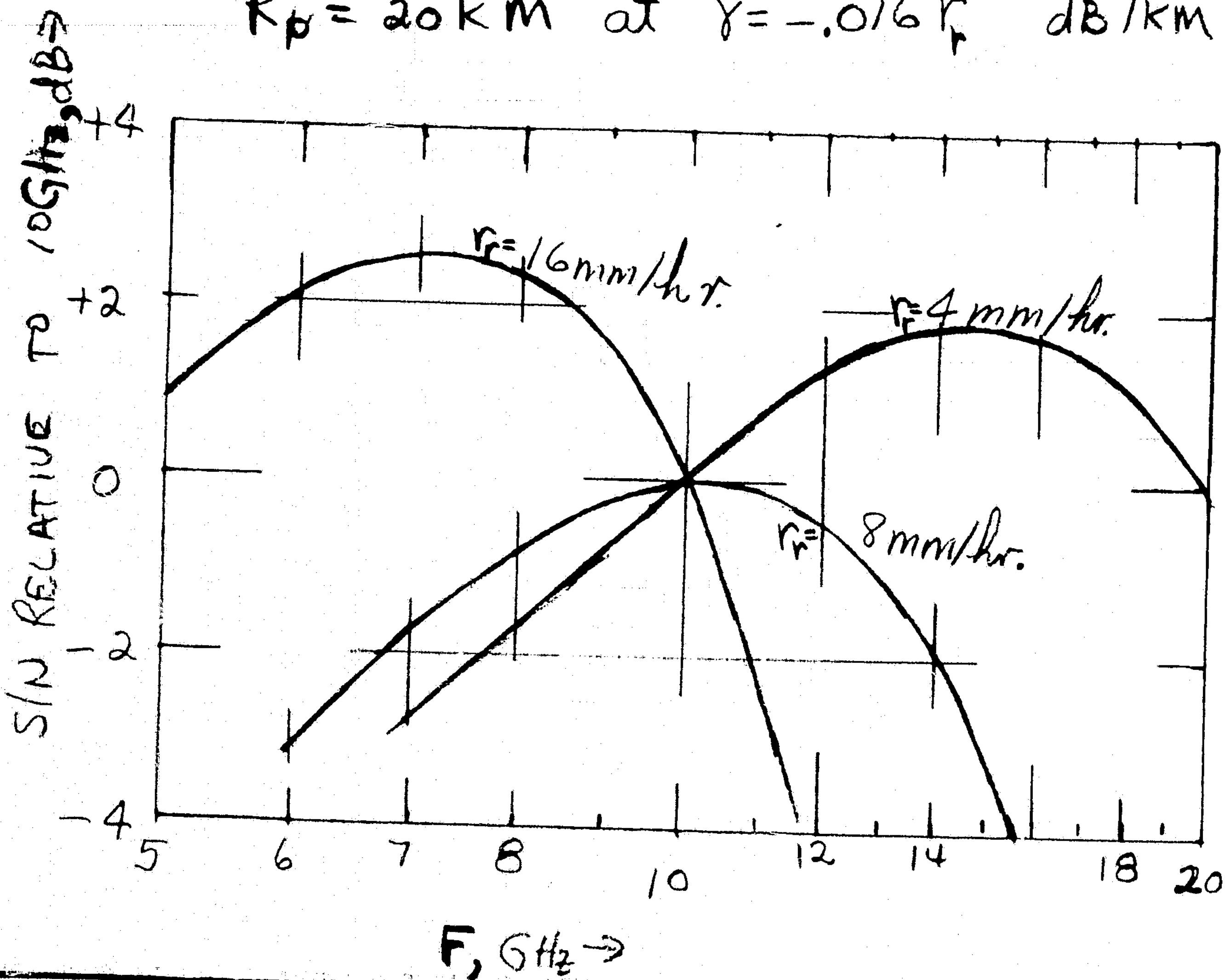
$R_p = 20\,km$ at $\gamma = -.016\, r_r^{1.31}$ dB/km (TWO-WAY)



NOTE:
CONSTANT TRANSMITTER POWER AND ANTENNA DIMENSIONS; (RECEIVE ELEMENTS $\propto F_\lambda$).

SUBSYSTEM DESCRIPTION

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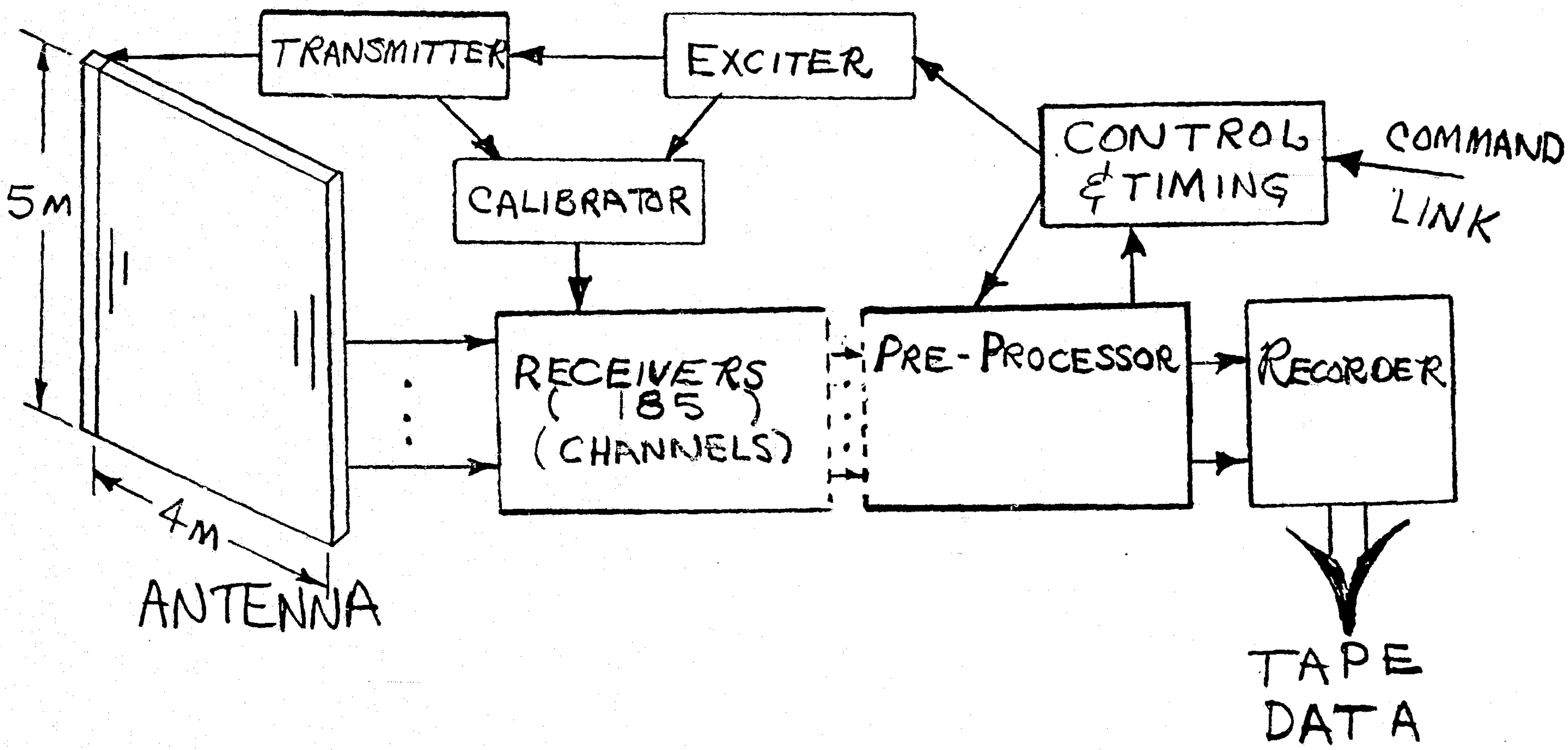
- ANTENNA
  - ELECTRICAL
  - THERMO-MECHANICAL
  - STOWAGE & DEPLOYMENT

- TRANSMITTER/RECEIVERS
  - EXCITER
  - MODULATOR
  - CALIBRATION

- PRE-PROCESSOR & RECORDER
  - AGC
  - A/D CONVERSION
  - BUFFERING


TRANSMITTER
EXCITER
CALIBRATOR
CONTROL & TIMING
COMMAND LINK
5m
4m
ANTENNA
RECEIVERS (185) (CHANNELS)
PRE-PROCESSOR
RECORDER
TAPE DATA

ARRAY SCHEMATIC

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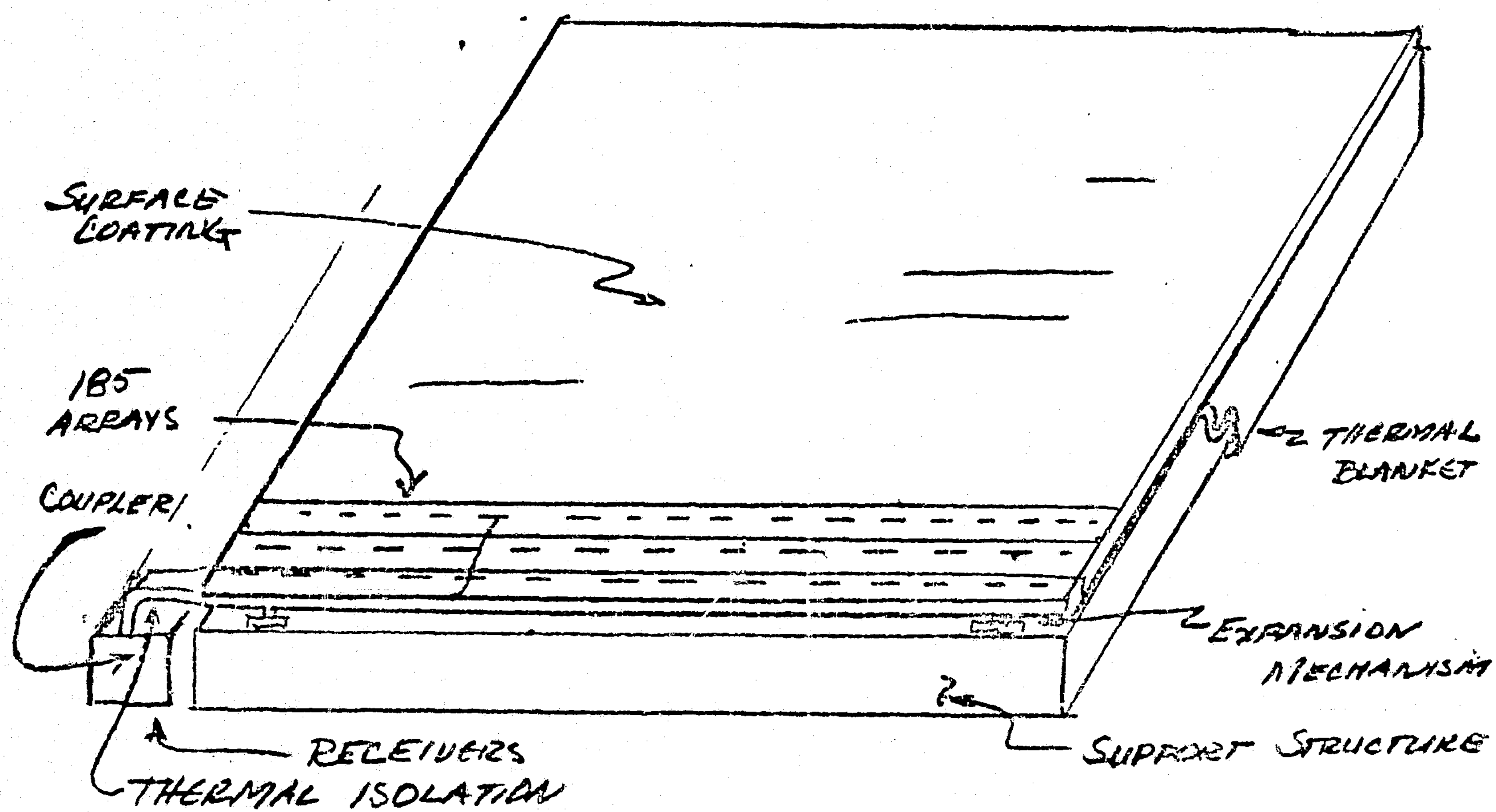
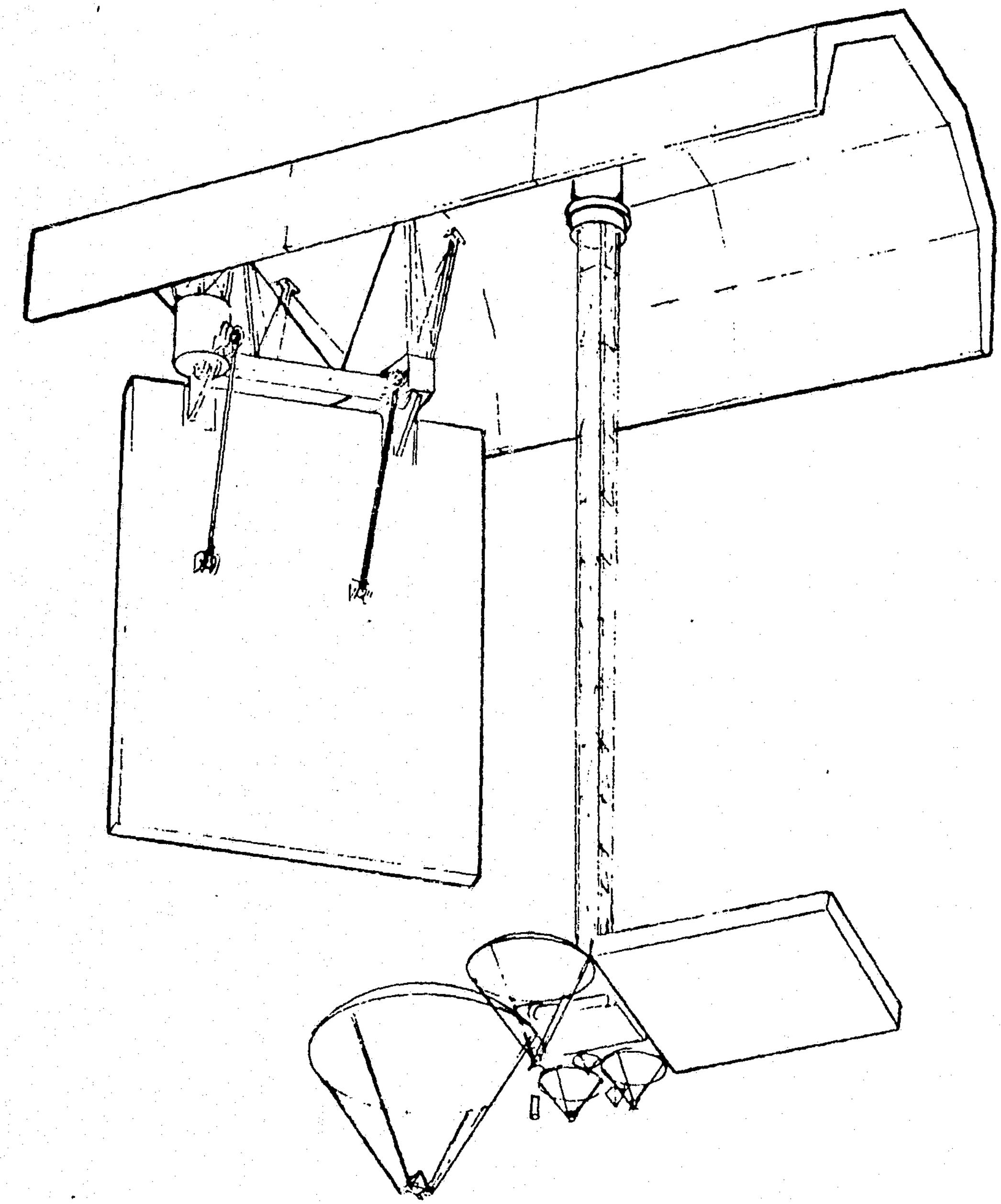


ORIGINATOR'S FACILITY/LOCATION



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MMAP/EEE ANTENNAS AND 4×5-M ARRAY SEPARATE MOUNT

MMAP/EEE ANTENNAS AND 4×5-M ARRAY SEPARATE MOUNT

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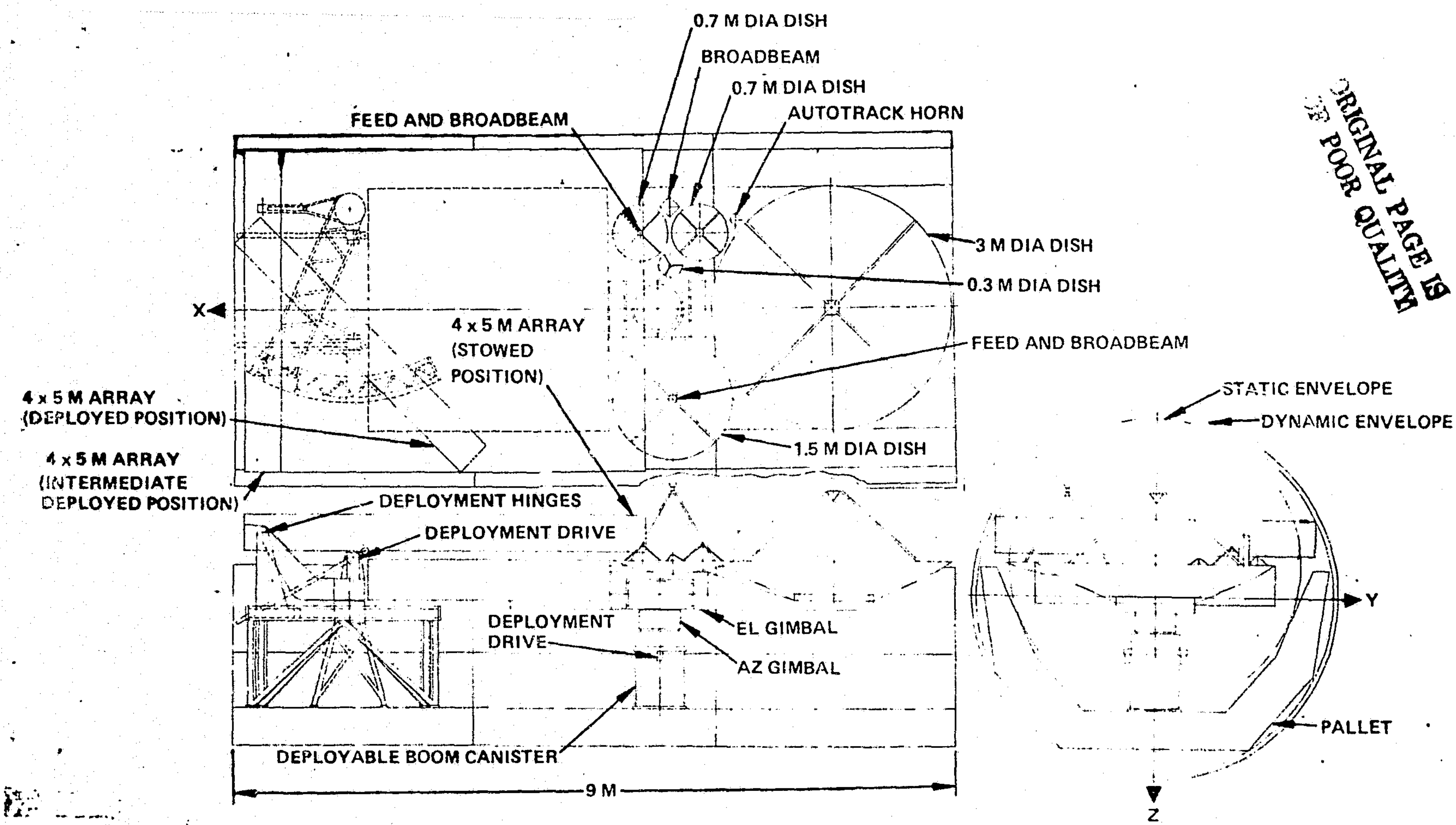
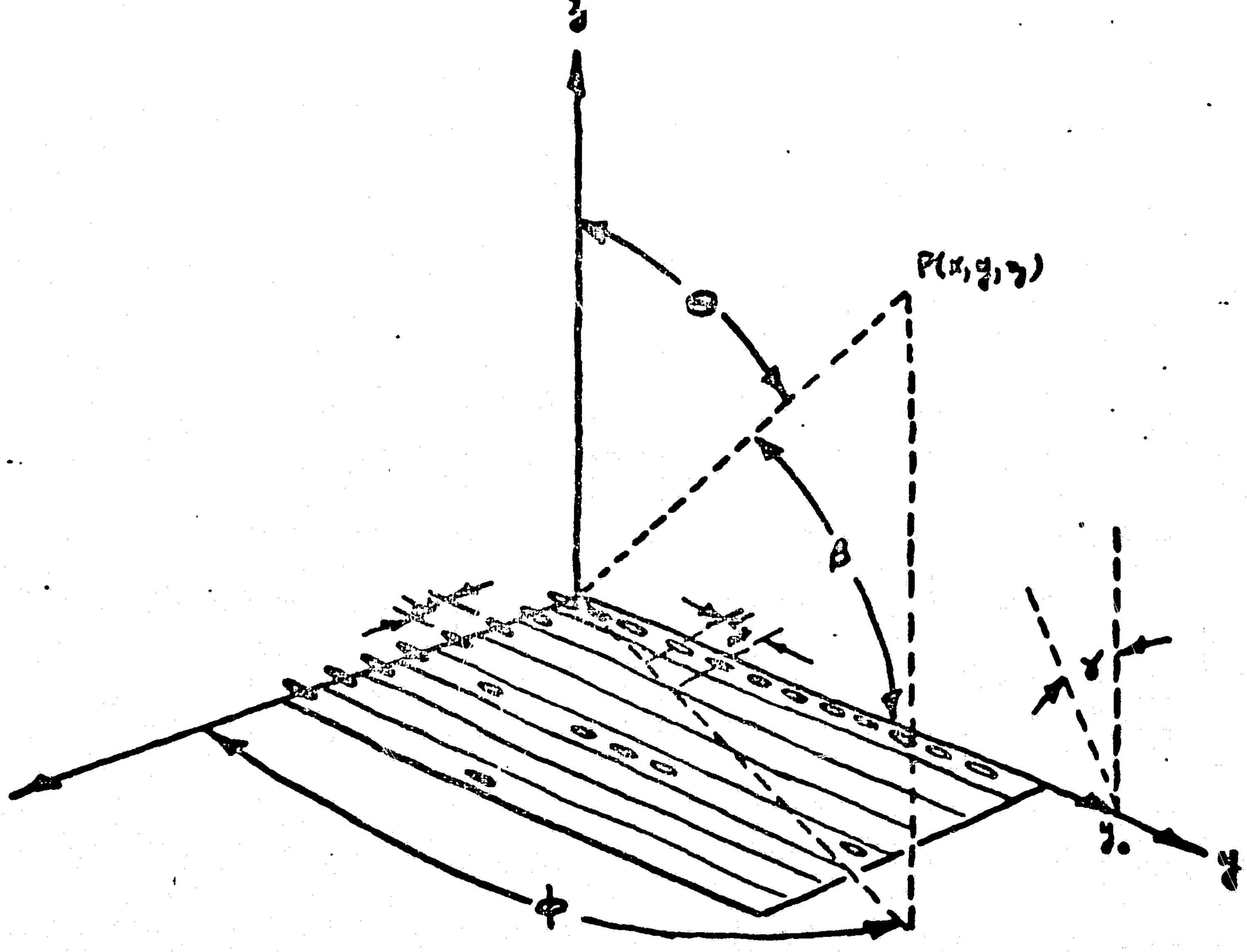
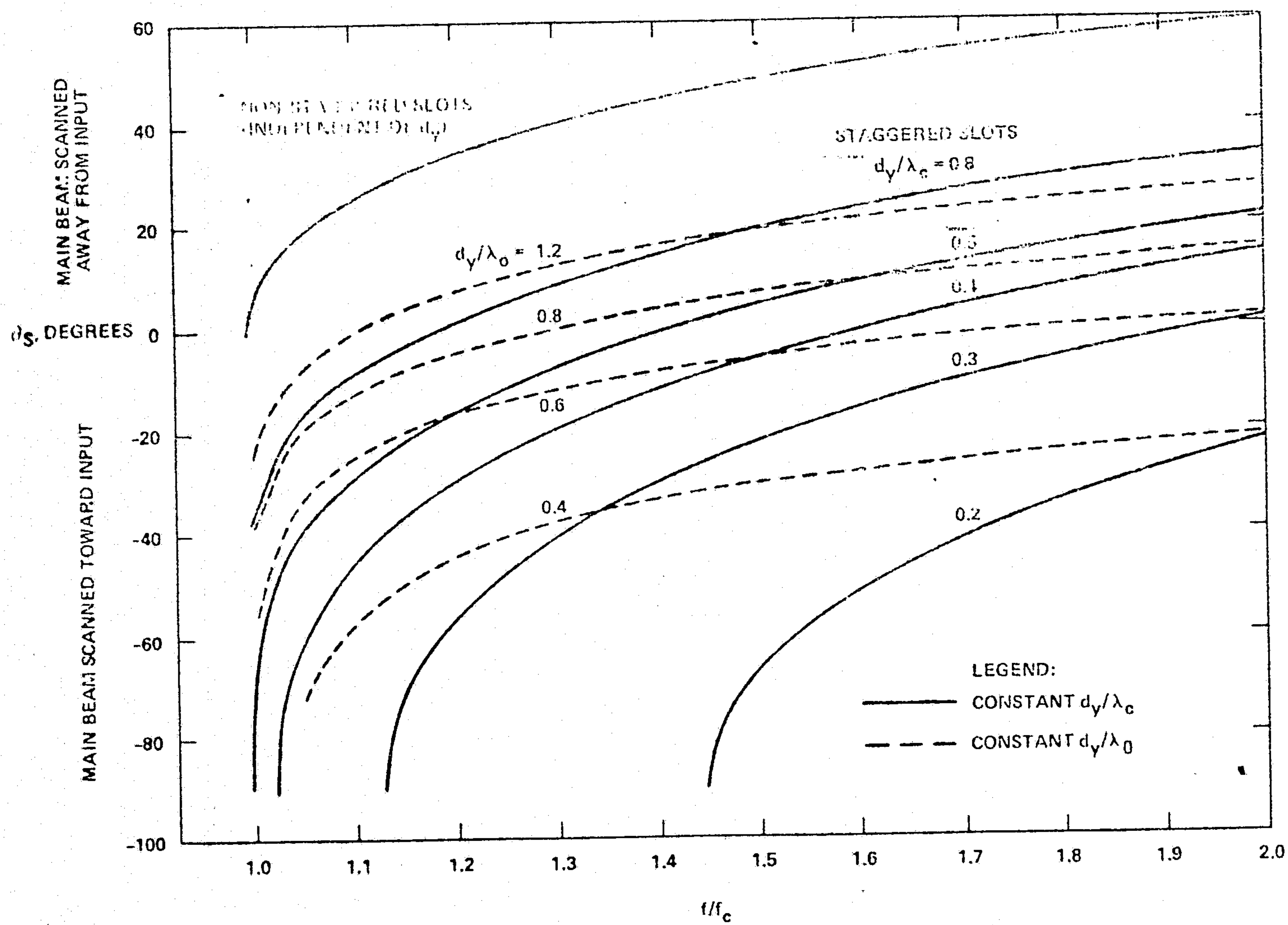
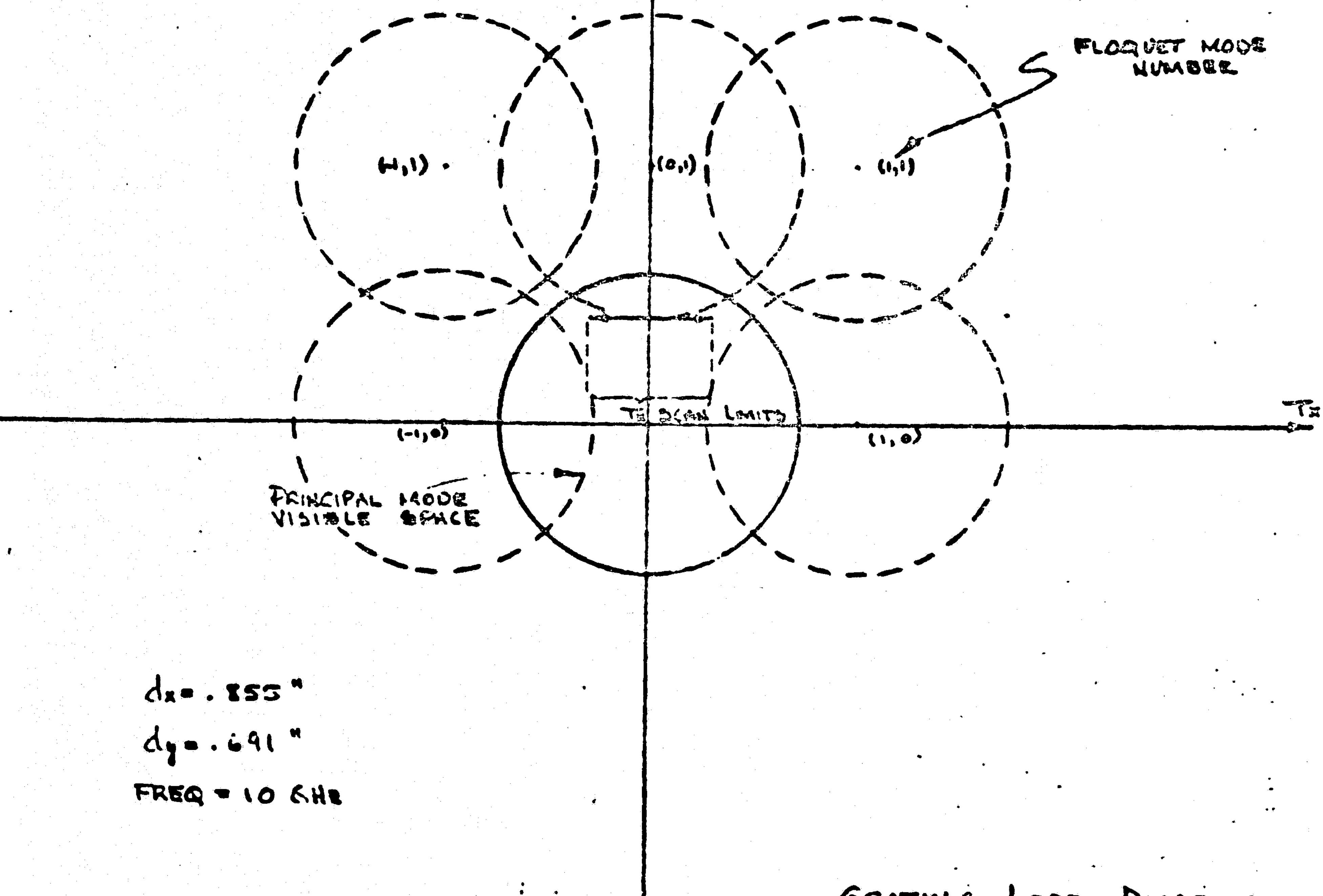




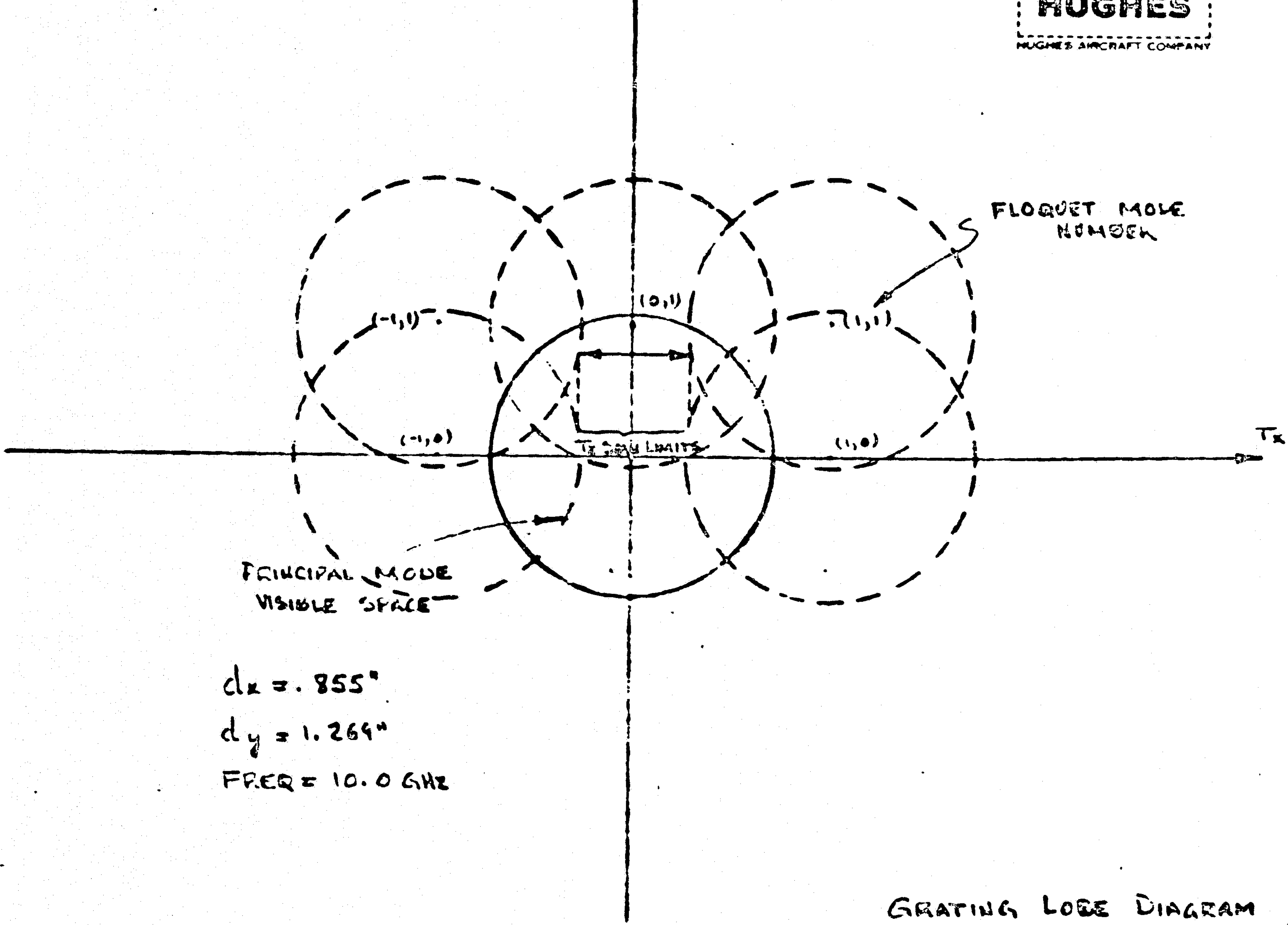
MRF PLANAR ARRAY IN COORDINATE SYSTEM

TRAVELING WAVE SLOT ARRAY SCAN ANGLE RELATIONSHIPS





GRATING LOBE DIAGRAM



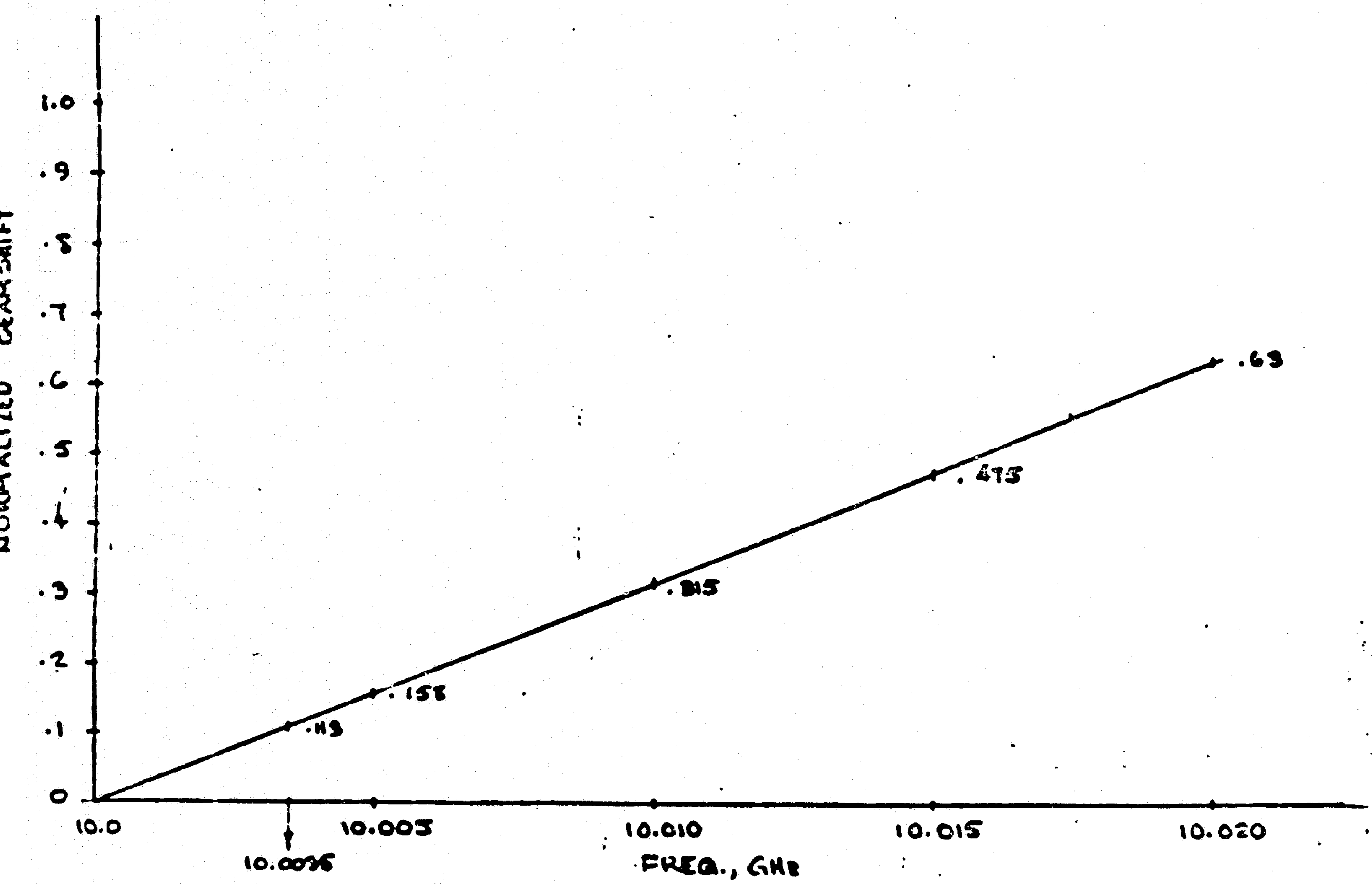
$d_x = .855"$

$d_y = 1.264"$

FREQ = 10.0 GHz

GRATING LOBE DIAGRAM

WAVEGUIDE BROAD DIMENSION = .835"



25 dB MODIFIED TAYLOR DISTRIBUTION (AMPLITUDE AND POWER)

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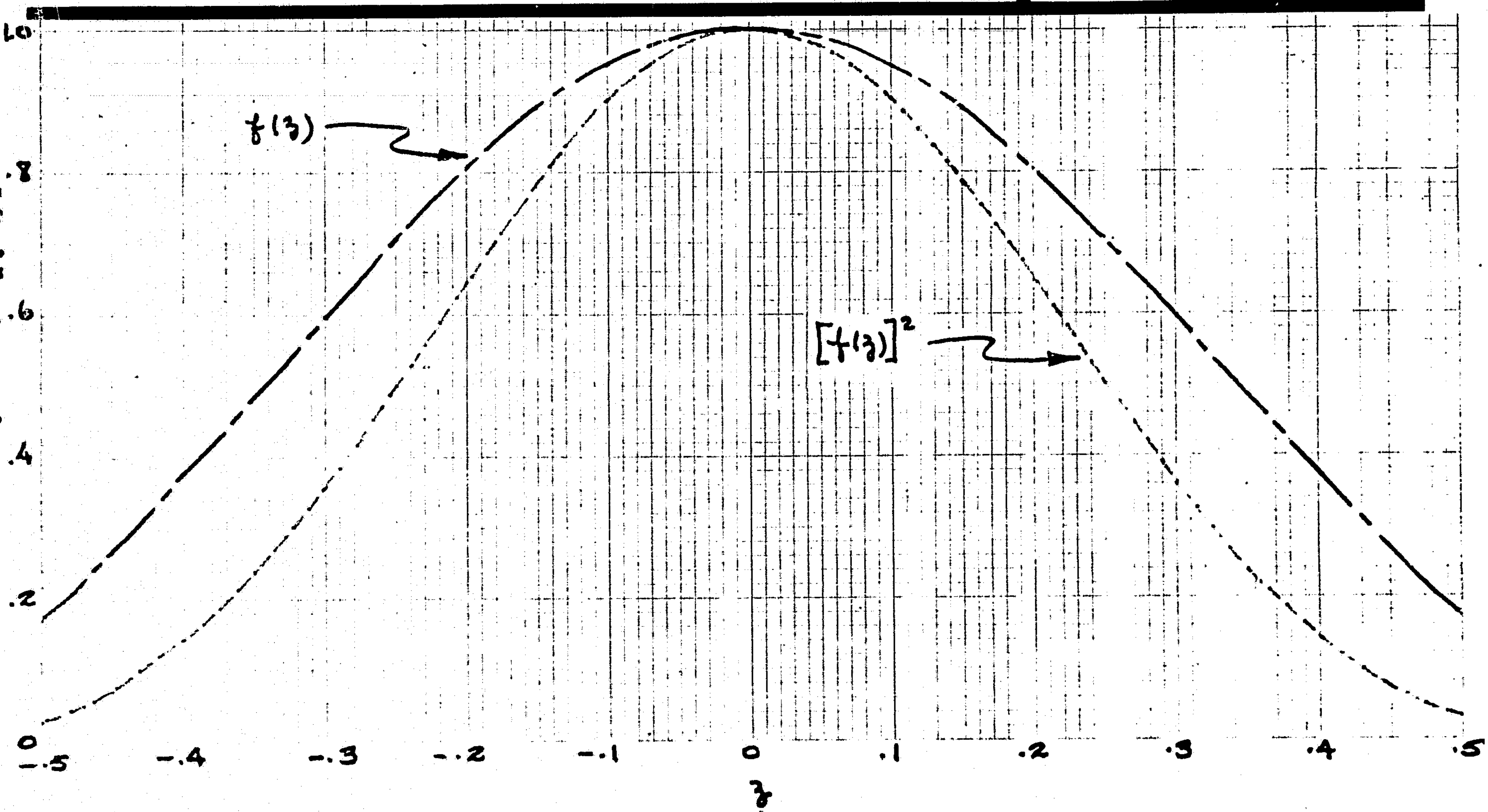
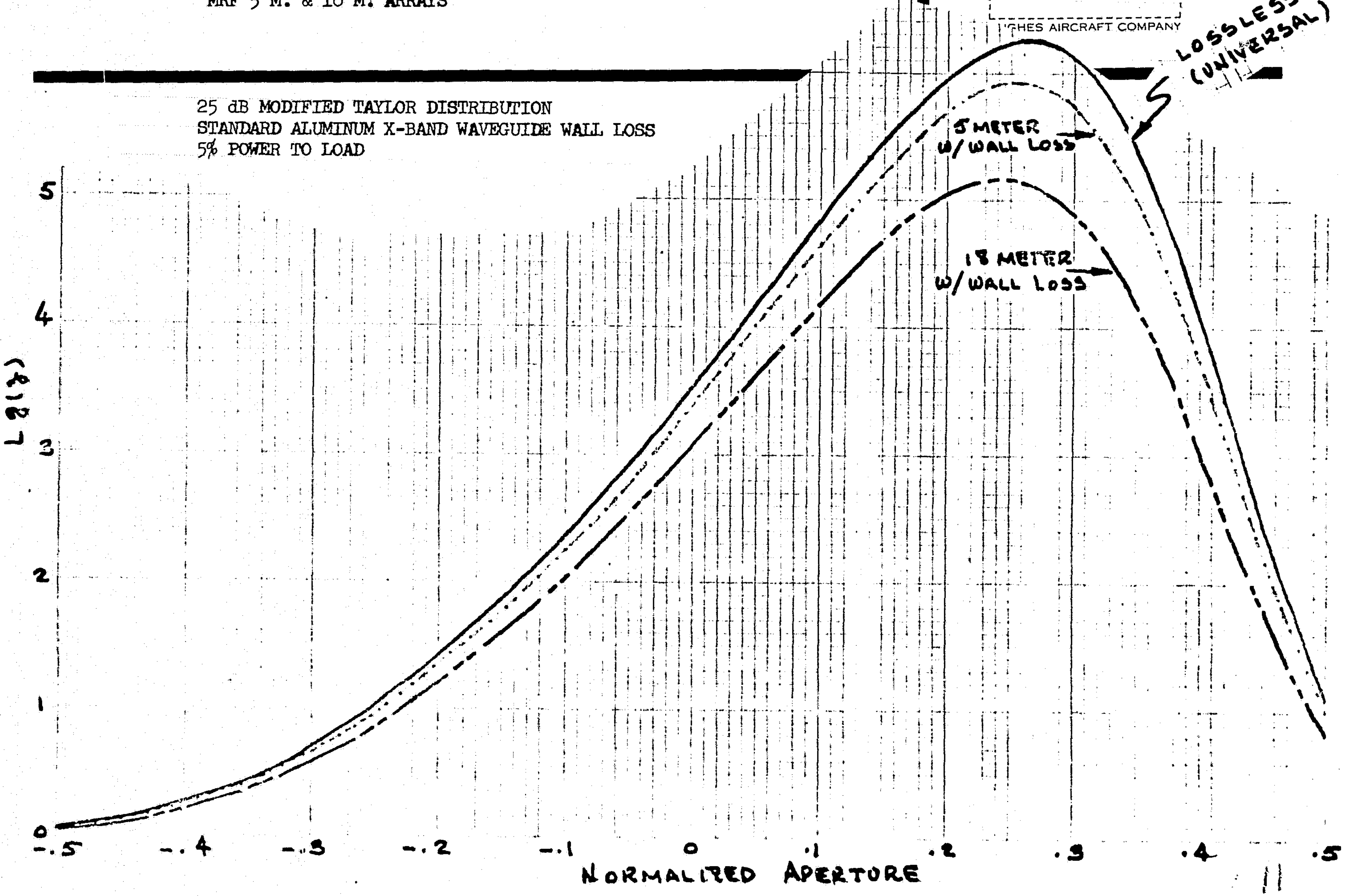
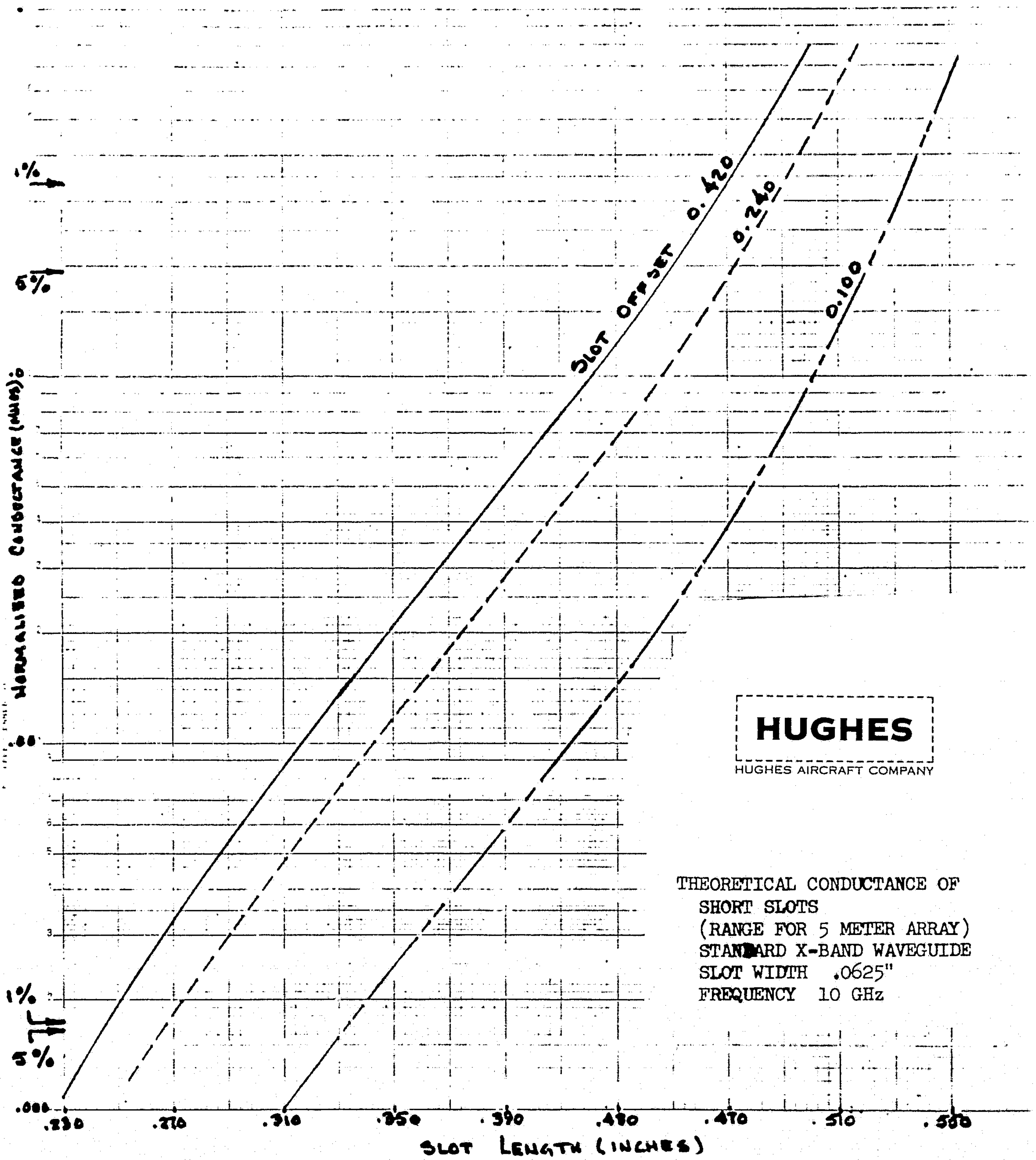


NORMALIZED CONDUCTANCE
MRF 5 M. & 18 M. ARRAYS

25 dB MODIFIED TAYLOR DISTRIBUTION
STANDARD ALUMINUM X-BAND WAVEGUIDE WALL LOSS
5% POWER TO LOAD





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THEORETICAL CONDUCTANCE OF
SHORT SLOTS
(RANGE FOR 5 METER ARRAY)
STANDARD X-BAND WAVEGUIDE
SLOT WIDTH .0625"
FREQUENCY 10 GHz

THEORETICAL SUSCEPTANCE OF SHORT SLOTS
(RANGE FOR 5 METER ARRAY)

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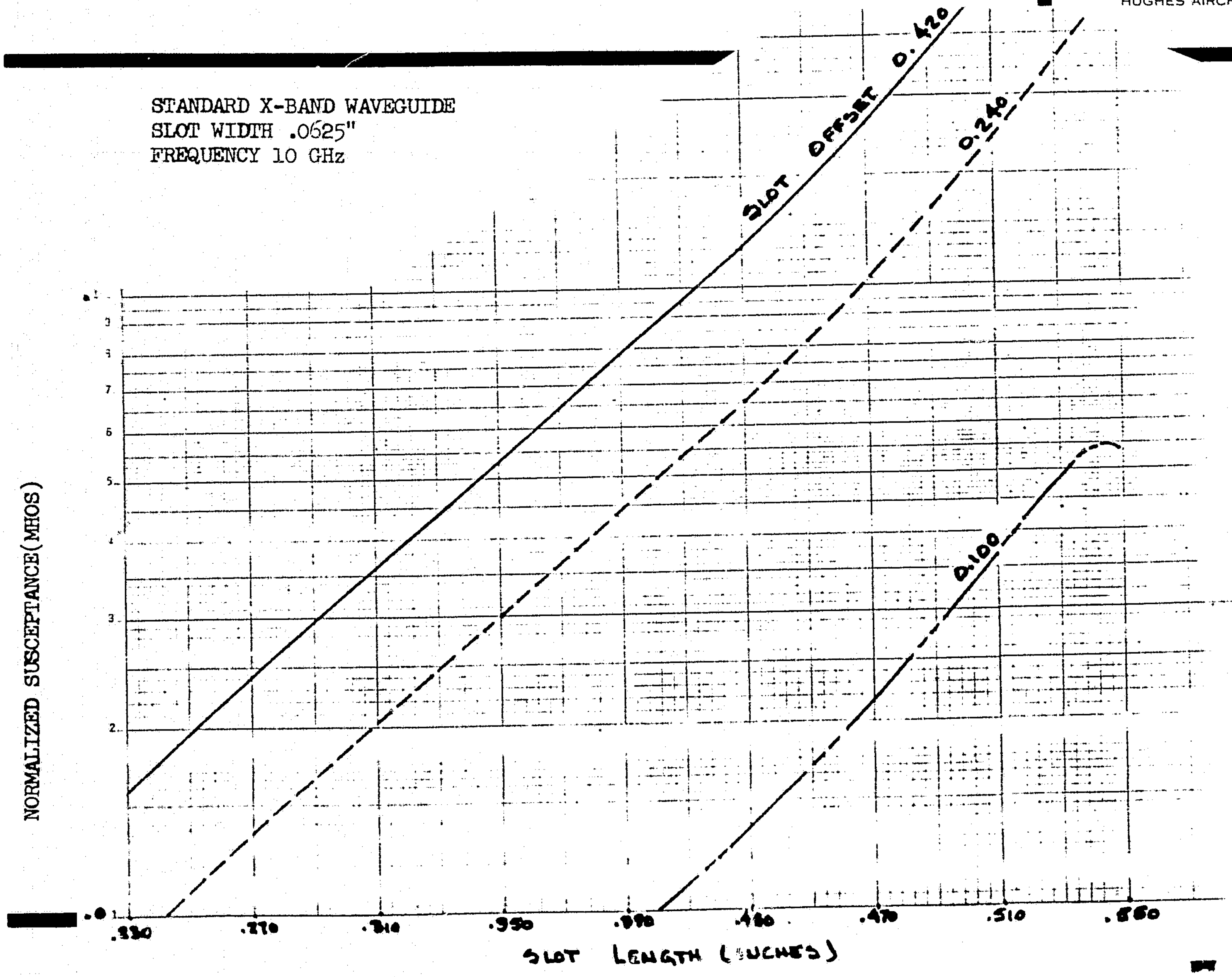

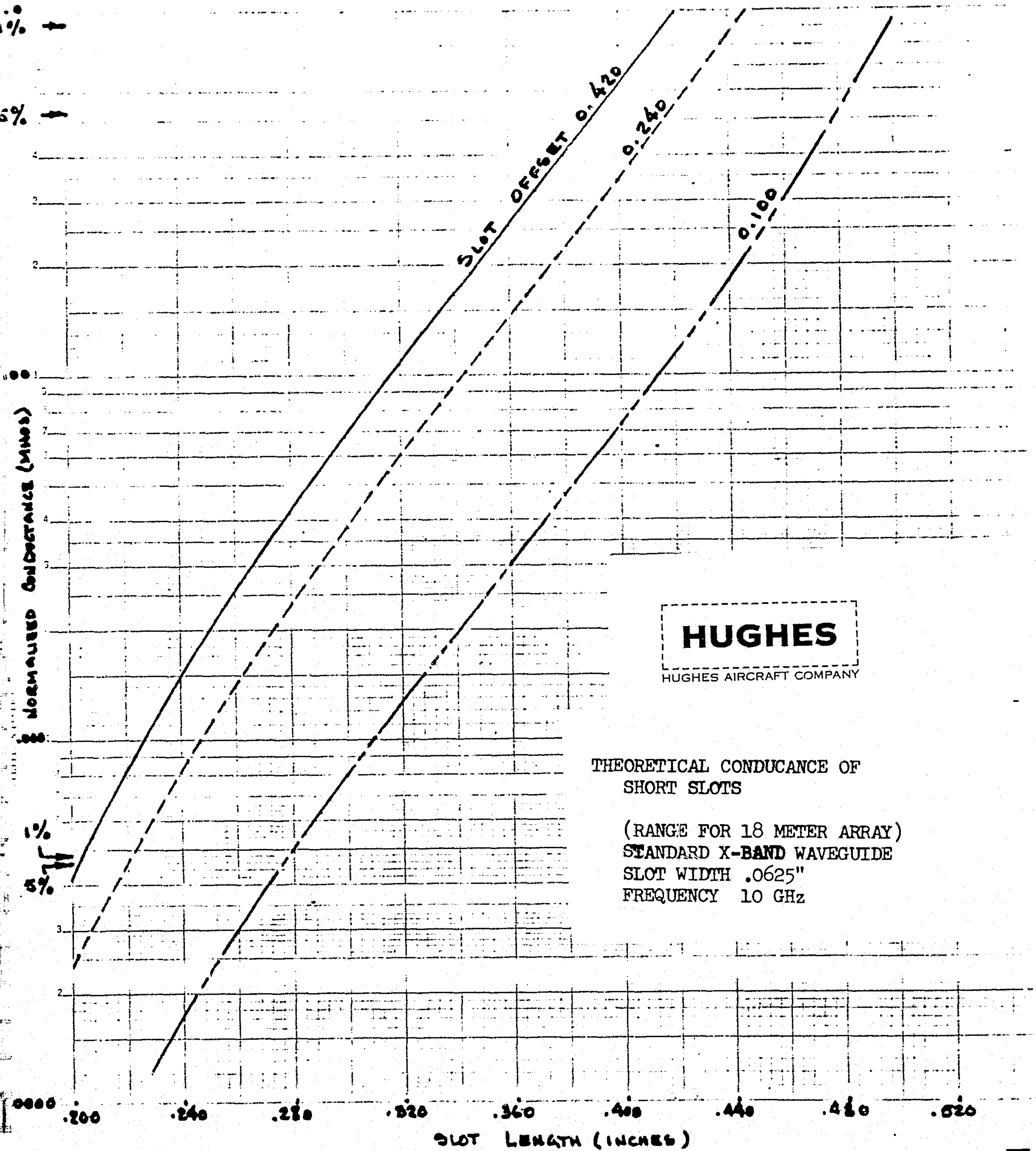

THEORETICAL CONDUCANCE OF
SHORT SLOTS

(RANGE FOR 18 METER ARRAY)
STANDARD X-BAND WAVEGUIDE
SLOT WIDTH .0625"
FREQUENCY 10 GHz

THEORETICAL SUSCEPTANCE OF SHORT SLOTS
(RANGE FOR 18 METER ARRAY)

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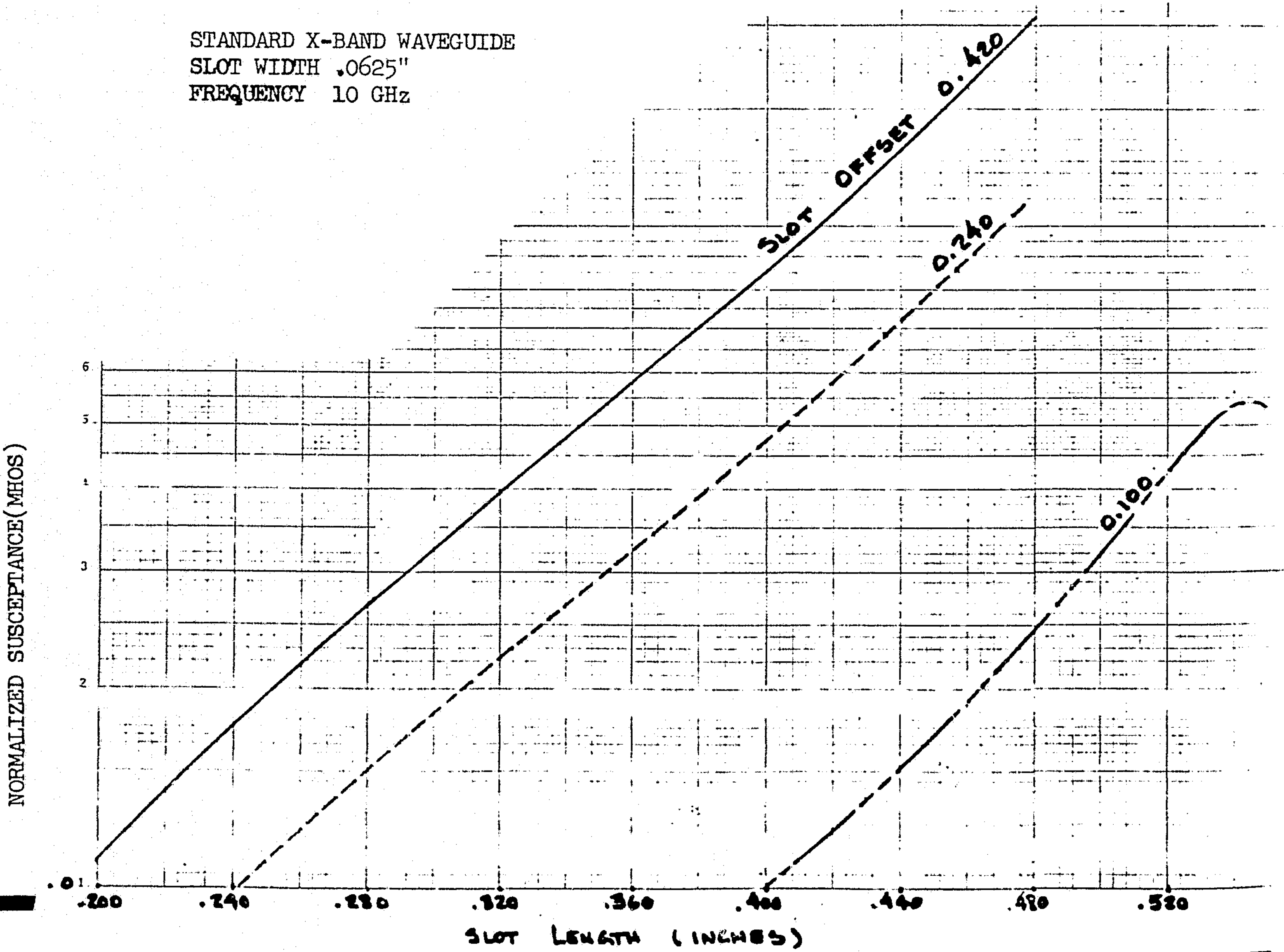
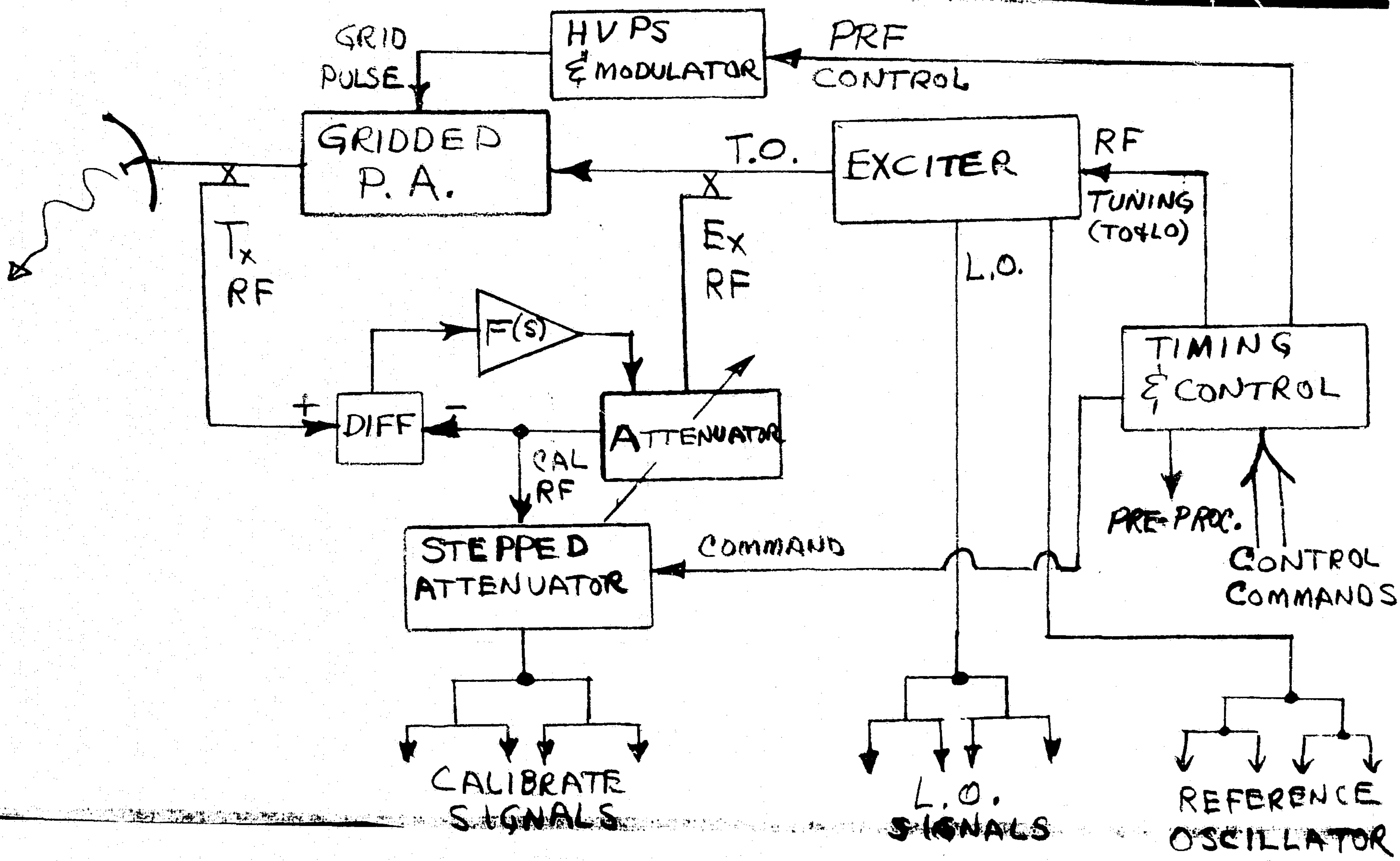
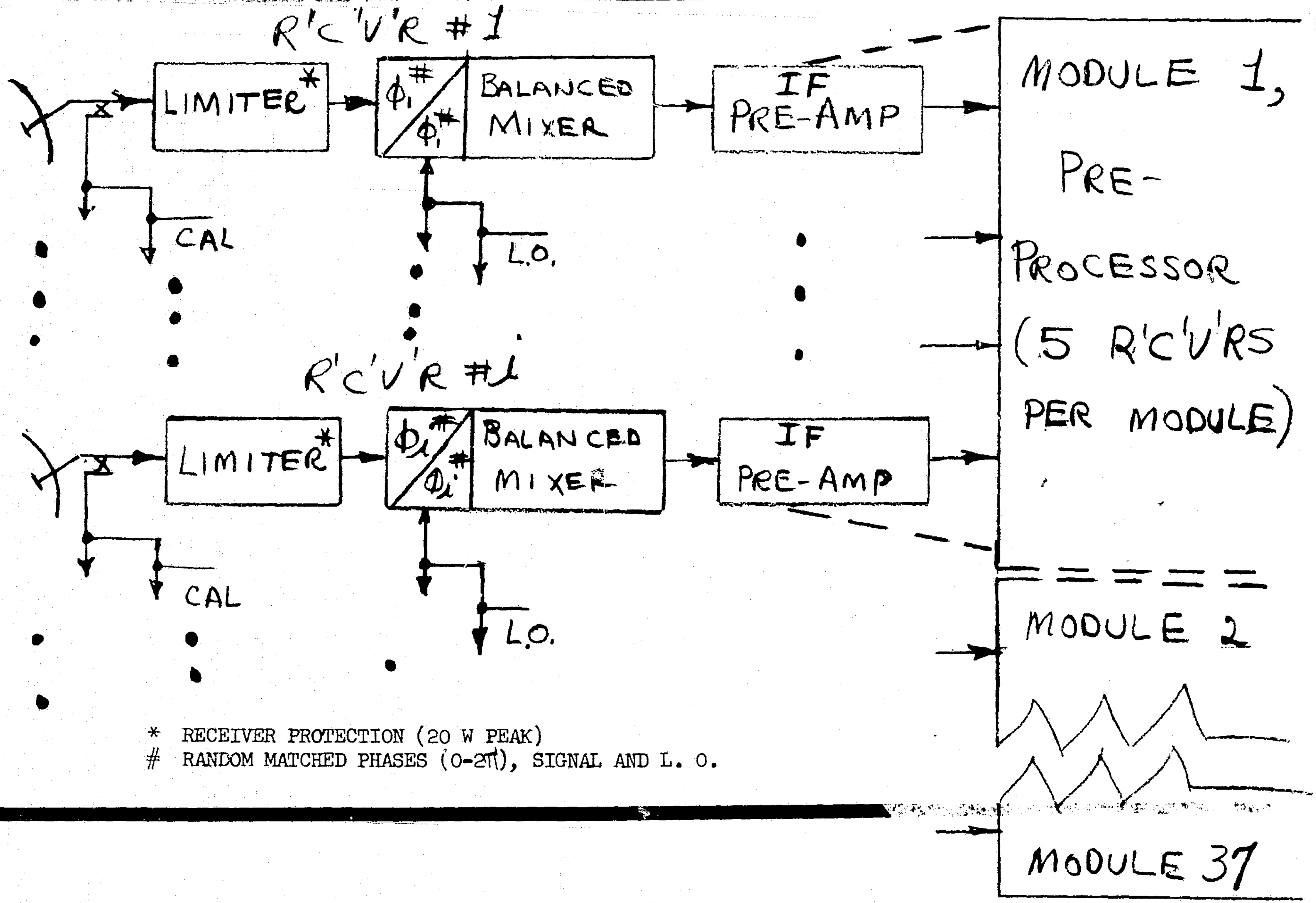



HV PS
& MODULATOR
GRID
PULSE
PRF
CONTROL
GRIDDED
P. A.
T.O.
EXCITER
RF
TUNING
(TO & LO)
Tx
RF
Ex
RF
L.O.
F(S)
+
DIFF
−
ATTENUATOR
CAL
RF
TIMING
& CONTROL
PRE-PROC.
STEPPED
ATTENUATOR
COMMAND
CONTROL
COMMANDS
CALIBRATE
SIGNALS
L.O.
SIGNALS
REFERENCE
OSCILLATOR



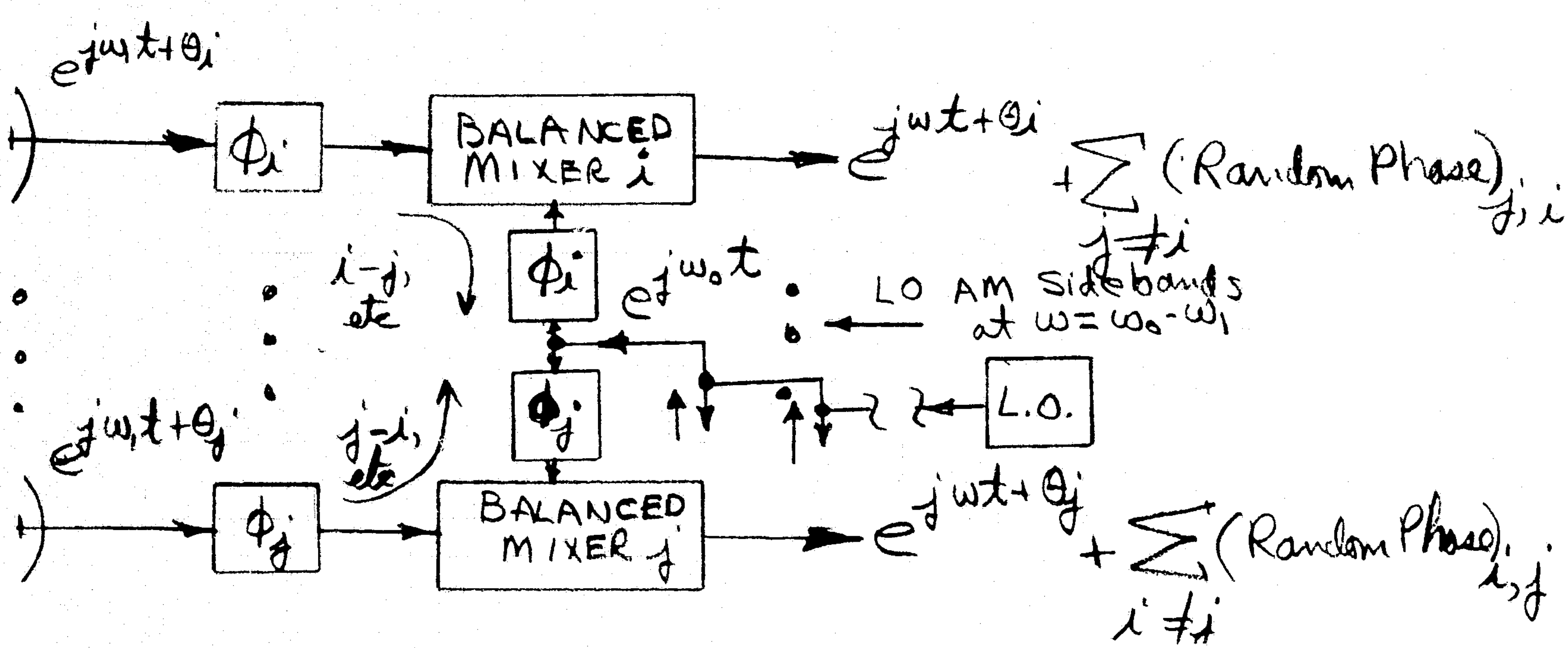
* RECEIVER PROTECTION (20 W PEAK)
\# RANDOM MATCHED PHASES (0-2π), SIGNAL AND L. O.

PHASE RANDOMIZATION

NON-COHERENT INTER-CHANNEL INTERFERENCE

- INTER-CHANNEL ISOLATION REQUIREMENT LESS THAN FOR CORRELATED INTERFERENCE
- AM NOISE SIDEBAND REQUIREMENT FOR COMMON L.O. SOURCE RELAXED

* (L.O. MANIFOLD IS A PRINCIPLE PATH FOR INTERCHANNEL COUPLING).



X-BAND TRANSMITTER OPTIONS FOR MRF

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1. EXISTING DESIGN AT HUGHES

TYPE:	GRIDDED TWT
FREQUENCY BAND:	9.6-9.8 GHz
POWER OUTPUT:	8-9 KW PK, 200-250 w. AVG.
DRIVE POWER:	20 MW (MAX)
INPUT REQUIREMENTS:	950 WATTS
APPLICATION:	DOPPLER RADAR, MILITARY

2. PROPOSED DESIGN FOR SPACE (SIR)

TYPE:	GRIDDED KLYSTRON
FREQUENCY:	9.0 GHz (75 MHz BW, 9-11 GHz)
POWER OUTPUT:	17 KW PK, 500 w. AVG.
RF DRIVE:	.6 w (MAX)
INPUT REQUIREMENTS:	1400 WATTS
APPLICATION:	COHERENT SYNTHETIC ARRAY RADAR

PRE-PROCESSOR ORGANIZATION

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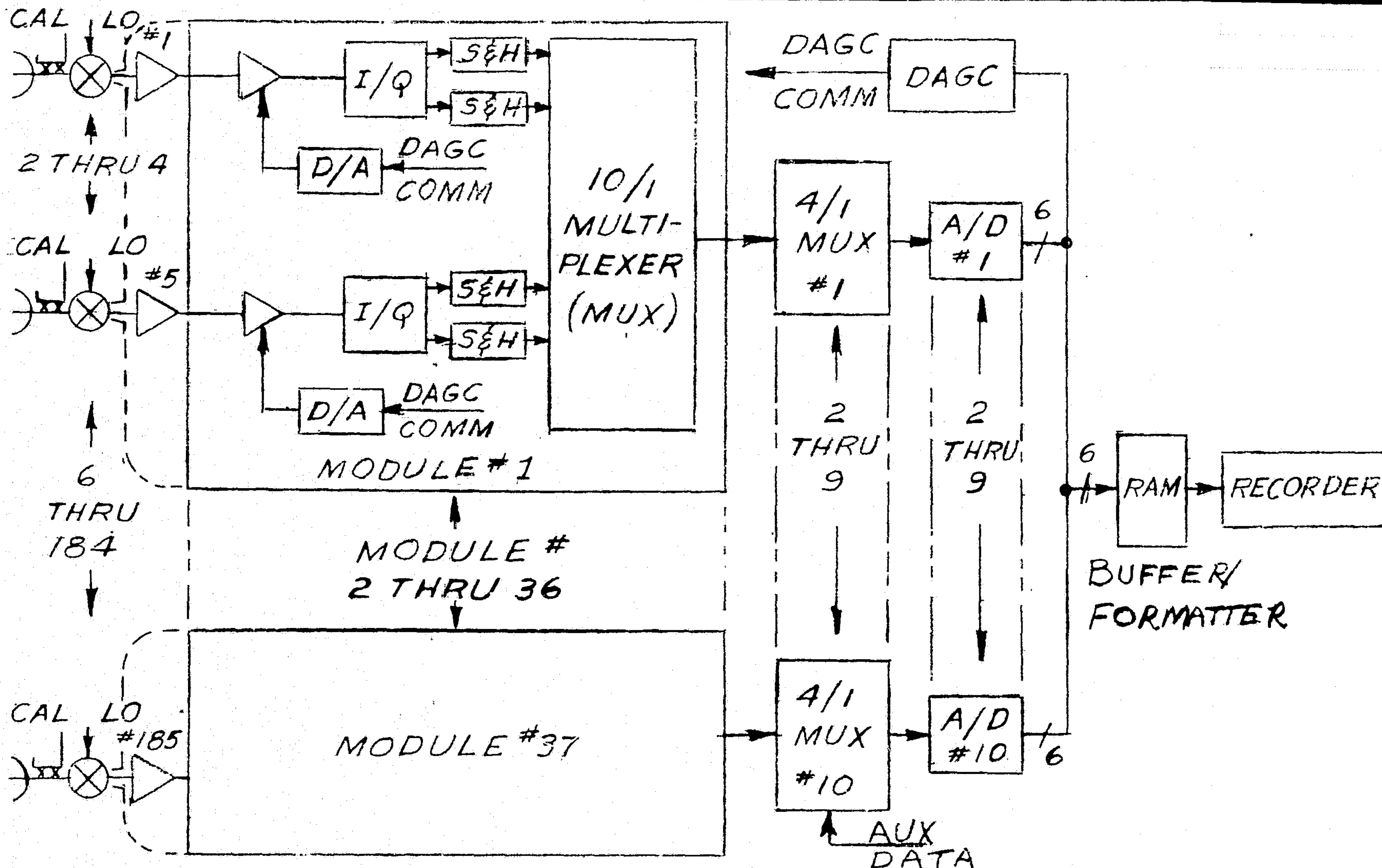

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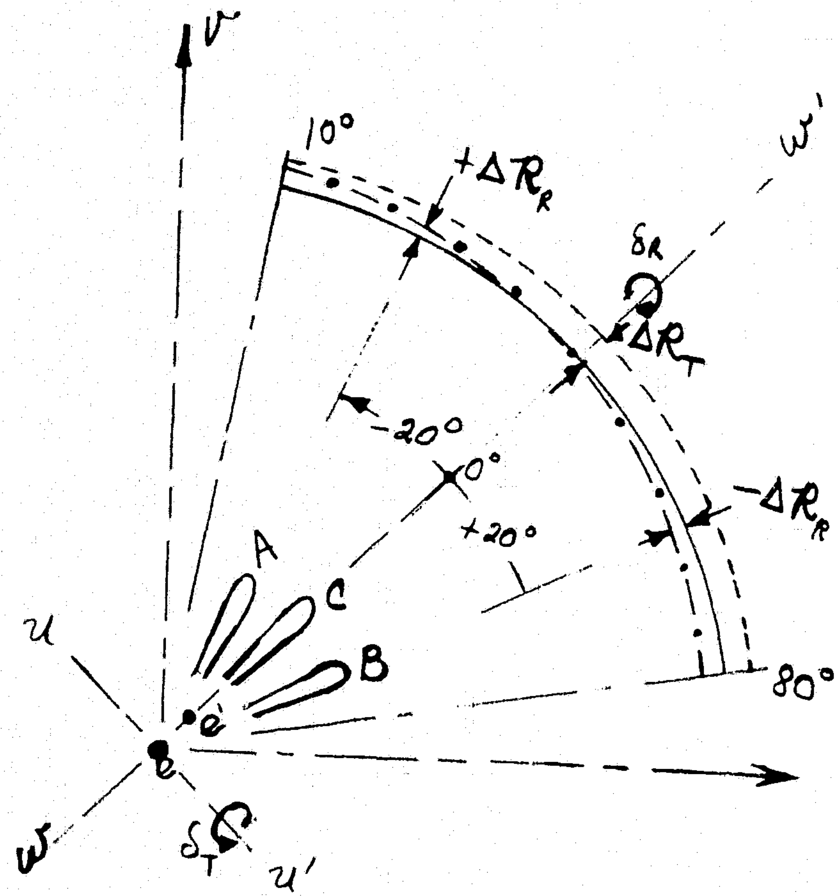
TILT AND ROTATION ERROR SENSOR: THREE BEAMS AT 0(C), 20(B),-20 (C) DEGREES
(RELATIVE TO ROTATIONAL AXIS W-W')



- CLUTTER RANGE SENSIVITIES TO ANTENNA POSITION:

  ROTATIONAL SENSITIVITY ΔR_R: ABOUT 2 KM/°

  TILT SENSIVITY ΔR_T: ABOUT 6 KM/°

- SENSOR SENSITVITIES:

  TO ROTATION: K_R = A-B, ABOUT 4KM/°

  TO TILT: $K_T = C - \frac{1}{2}(A\ B)$, ABOUT .36KM/°

NOTES:
ORBIT ALTITUDE: 200 KM
ANTENNA BEAMS AT NADIR ANGLE 46.6°
W-W': ROTATIONAL AXIS
U-U': TILT AXIS

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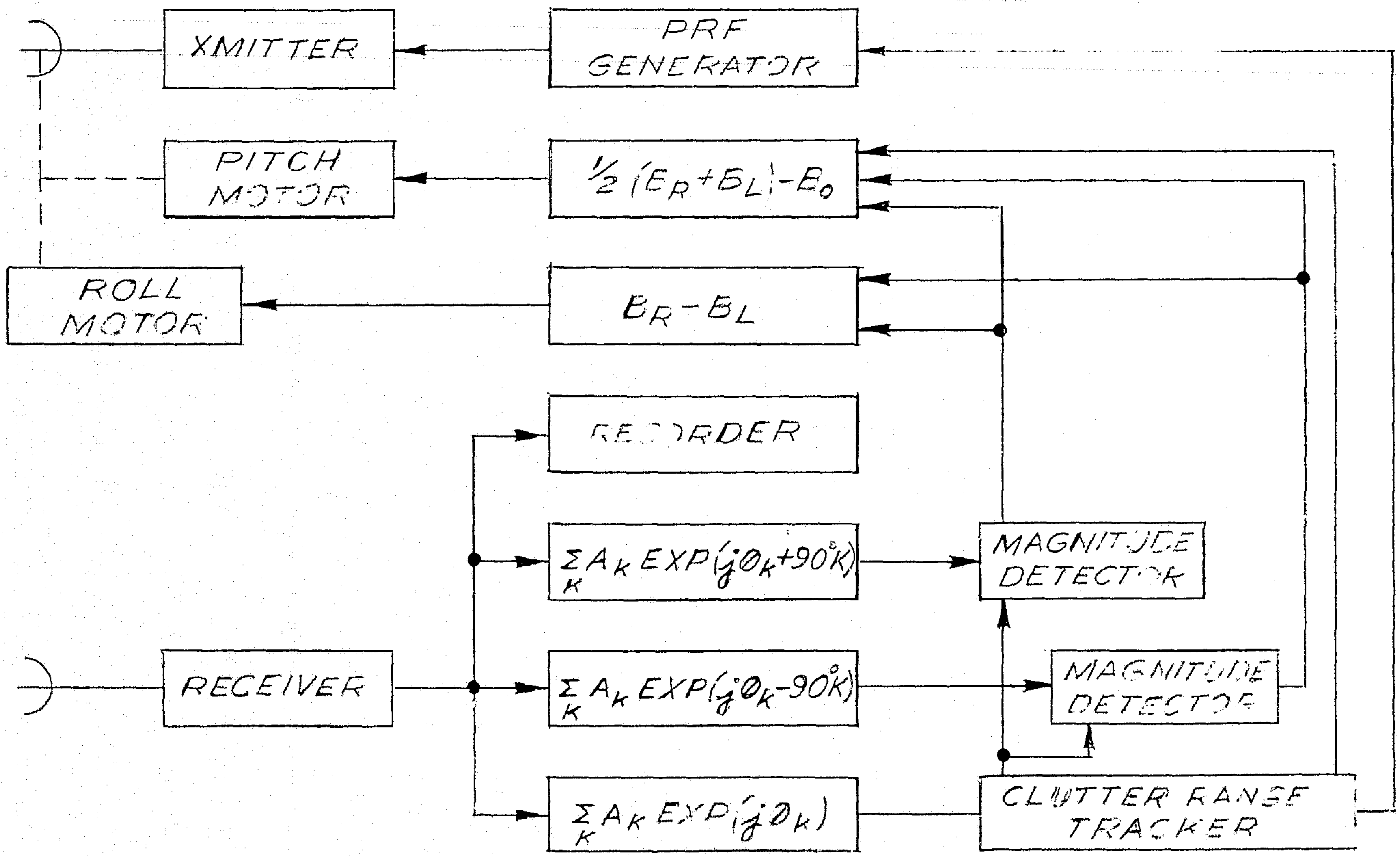
UDE CONTROL



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RECORDER OPTIONS FOR MRF

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1. RCA HDMR 240

TRACKS:	≥ 120 FOR SIGNAL DATA
BIT RATE:	120 MB/S AT 152 CMS/SEC (60 IPS)
RECORD TIME PER REEL:	30 MIN. AT 120 MB/S
POWER/WEIGHT:	200 w/90 Kg

STATUS: UNDER PHASED DEVELOPMENT, FLIGHT MODEL 1ST QUARTER 1979?

2. ADVANCED DEVELOPMENTS;

E.G:	AMPEX AR1700
BIT RATE:	100 MB/S ON 28 TRACKS AT PACKING DENSITIES OF 11.8 KB/CM (30 KB/IN.)
RECORD TIME PER REEL:	15 MIN AT 100 MB/S (120 IPS)
POWER/WEIGHT:	450 w/40 Kg

STATUS: UP-GRADING DEVELOPMENT MODELS; AVAILABLE 90-120 DAYS ARO

TOPICS:

- SYSTEM
- ANTENNA
- TRANSMITTER
- EXCITER
- RECEIVERS
- CALIBRATOR
- PRE-PROCESSOR
- DISTRIBUTION NETWORKS

CARRIER FREQUENCY F_X: TO BE SELECTED IN BAND 9.5 TO 10.5 GHz (10.0 GHz BASELINE)

ORBIT ALTITUDE: 200 $\pm$ 30 KM

ORBIT INCLINATION: AS REQUIRED

SPACELAB LOCAL VERTICAL: EARTH ORIENTED

DRIFT: TBD DEGREES/MINUTE

ACCURACY: TBD DEGREES RMS

ANTENNA

DIMENSIONS: 4X5 METERS $\pm$ 10%

POLARIZATION: LINEAR HORIZONTAL

ELEVATION SIDELOBES: -25 dB PEAK (ONE WAY)

GRATING LOBES: -25 dB (ONE WAY)*

RECEIVE ELEMENTS: 175-195 (PROPORTIONAL TO F_X; 185 @10 GHz)

AZIMUTH SIDELOBES (LIMIT IMPOSED BY REAL ARRAY): -40 dB RMS (ONE WAY)*

ELEMENT PATTERN BEAMWIDTHS: 70 DEGREES MINIMUM IN AZIMUTH; .6 DEGREES MAXIMUM IN ELEVATION

* OUTSIDE $\pm$ 4 BEAMWIDTHS OF MAINLOBE

TRANSMITTER

PEAK POWER: 8KW MINIMUM

POWER AMPLIFIER: GRIDDED KLYSTRON OR TWT

TUBE BANDWIDTH: 25 MHz MINIMUM

NOMINAL PULSE WIDTH: 6.67 μs

AVERAGE POWER OUTPUT: 250 WATTS MAXIMUM

EXCITER

CARRIER FREQUENCIES (3): $F_1=F_X$, $F_2=F_X+1.5$ MHz, $F_3=F_X-1.5$ MHz

OUTPUTS; DRIVE: .3 WATT MINIMUM
L. O.: 2.0 WATTS MINIMUM
REF. OSC.: .1 WATT MINIMUM

RECEIVERS

NOISE FIGURES: 10 dB MAXIMUM

IF: 30 MHz WITH BANDWIDTHS OF 1.0±10% AT -3dB AND 2.3 MHz MAXIMUM AT -20 dB

GAIN AND PHASE BALANCES: .6 dB, 4° RMS OVER BANDWIDTH OF 330 KHz ± 10%

MIXER LO CARRIER SUPPRESSION: 20dB MINIMUM

CALIBRATOR

OUTPUT (REFERENCED TO TRANSMITTER SAMPLES P_C=10 MW, MINIMUM):

-15 dB TO -63 dB IN 3dB STEPS WITH ACCURACY ±.15dB RMS

PRE-PROCESSORS

IF POSTAMPLIFIER NOMINAL GAIN: 50±3 dB MAXIMUM

DIGITAL GAIN CONTROL RANGE: 30 dB WITH .1 dB RMS ACCURACY

MUTUAL DE-COUPLING: AT LEAST 50 dB ISOLATION BETWEEN RECEIVERS IN A COMMON MODULE AND 80 dB ISOLATION BETWEEN RECEIVERS IN SEPARATE MODULES; 10 RECEIVERS MAXIMUM PER MODULE

TIME MULTIPLEX: TWO CASCADED STAGES TO MULTIPLE PARALLEL A/D CONVERTER CHANNELS

SAMPLE/HOLD APERTURE TIME: 100 NS MAXIMUM

DE-COUPLING: 40 dB MINIMUM ISOLATION BETWEEN ADJACENT DIGITAL WORDS

A/D CONVERTER BIT OUTPUT (BIT SELECTION): 5 MOST OR 5 LEAST SIGNIFICANT BITS (I&Q) SELECTED FROM 6 BITS I AND Q

CLUTTER RANGE TRACKER: 500 METERS MAXIMUM RMS ERROR TO MEAN MAIN LOBE CLUTTER RANGE

DIFFERENTIAL CLUTTER RANGE SENSOR: SENSITIVE TO MEAN CLUTTER RANGE DIFFERENCES OF 100 METERS OR LESS AT BEAM POSITIONS OF 0°, ± 20° RELATIVE TO ARRAY BROADSIDE

- LOCAL OSCILLATOR (185 PORTS);

  FORM: CORPORATE FEED

  INSERTION LOSS: 7 dB MAXIMUM

  GAIN BALANCE: 1 dB RMS

  PHASE BALANCE: 4^{o} RMS

  INTER-CHANNEL RF SIGNAL ISOLATION:* 41 dB MINIMUM INCLUDING CARRIER SUPPRESSION CONTRIBUTION OF 20 dB MINIMUM PER RECEIVER MIXER

- CALIBRATOR (185 PORTS):

  FORM: CORPORATE FEED

  INSERTION LOSS: 7 dB, MAXIMUM

  GAIN BALANCE: .8 dB RMS

  PHASE BALANCE: 3^{o} RMS

  INTER-CHANNEL RF SIGNAL ISOLATION:* 50 dB, MINIMUM INCLUDING 50 dB MINIMUM PER CHANNEL COUPLER PAIR

---

* ISOLATION REFERS TO RF SIGNAL PORT-TO-IF SIGNAL PORT OVER RELEVANT COUPLING NETWORK PATH.

- REFERENCE OSCILLATOR (185 INJECTION POINTS IN GROUPS OF 10 MAXIMUM EACH):

GAIN BALANCE:	1 DB RMS
PHASE BALANCE:	4^{o} RMS
INTER-CHANNEL ISOLATION:*	
INTRA-GROUP:	50 DB MINIMUM
INTER-GROUP:	80 DB MINIMUM

* INCLUDING ACTIVE ELEMENTS, AS REQUIRED; ISOLATION REFERS TO IF SIGNAL PORT-TO-VIDEO SIGNAL PORT OVER RELEVANT COUPLING NETWORK PATH

TRANSMITTER SPECIFICATIONS

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OPERATING TEMPERATURE RANGE -20^{o} TO $+40^{o}$ C

PEAK POWER, MINIMUM	8.0 KW
GAIN MINIMUM	45 DB
DRIVE MAXIMUM	0.3 WATT
PULSE DURATION, NOMINAL	6.67 us
PRF, MAXIMUM	10.0 KHz
AVERAGE DUTY FACTOR, MAXIMUM (1)	2.5%
GAIN DRIFT, MAXIMUM	0.3 DB IN 5 MINUTES
PM AND AM SIDEBANDS	
MAXIMUM, ANY F 1 KHz	-40 DB PER 100 Hz
RF POWER DROOP IN 10 us, MAXIMUM	0.3 DB
TRANSMITTER TUBE BANDWIDTH, MINIMUM	25 MHz

NOTES:
(1) ONE (1) SECOND MAXIMUM AVERAGING TIME
(2) AFTER 10 MINUTE WARMUP

EXCITER SPECIFICATIONS

HUGHES

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OPERATING TEMPERATURE RANGE	-20^{0} TO $+40^{0}$C
CARRIER FREQUENCIES (1)	$F_1 = F_x$, $F_2 = F_x$+1.5 MHz, $F_3 = F_x$-1.5 MHz
DRIVE OUTPUT (GATED)	0.3 WATT, MINIMUM
LOCAL OSCILLATOR OUTPUTS:	
FREQUENCIES (2)	F_i +30.0 MHz; i = 1, 2, 3
POWER	2.0 WATTS, MINIMUM
TUNING TIME	25 us, MAXIMUM
STABILITIES:	
CARRIER FREQUENCY F_x	$\pm 0.2\%$
TO AND LO NOISE SIDEBANDS, MAXIMUM	-55 DB PER KHz AT F > 1 KHz -75 DB PER KHz AT F > 20 KHz
DRIVE POWER OUTPUT	
MAXIMUM DEVIATION	$\pm$.5 DB
MAXIMUM DRIFT	$\pm$.2 DB IN 5 MINUTES
LOCAL OSCILLATOR AM NOISE SIDEBAND	-113 DB PER 100 KHz AT 30 MHz
REFERENCE OSCILLATOR	
OUTPUT POWER	100 mw, MINIMUM
FREQUENCY TUNING RANGE	29.7 TO 30.3 MHz

(1) F [illegible] 10 GHz (NOMINAL) FOR THE BASELINE DESIGN: F_x WILL BE SELECTED IN THE RANGE 9.5-10.5 GHz, DEPENDING UPON FREQUENCY ALLOCATION AND TRANSMITTER TUBE AVAILABILITY. THE BASELINE DESIGN PROVIDES FREQUENCY AGILITY WITH THREE CARRIER FREQUENCIES STAGGERED 1.5 MHz.

(2) LOCAL OSCILLATOR FREQUENCIES ARE TUNED WITH A TIME DIFFERENTIAL RELATIVE TO TRANSMISSION OF 1.46 MS (170 KM ALTITUDE) TO 2.06 ms (230 KM ALTITUDE).

RECEIVER SPECIFICATIONS

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OPERATING TEMPERATURE RANGE	-20^{o} TO $+40^{o}C$
NUMBER	185
NOISE FIGURE, MAXIMUM	10 DB
IF	30 MHz
BANDWIDTHS:	
3 DB	1.0 MHz $\pm 10\%$
20 DB	2.3 MHz MAXIMUM
PRE-AMP GAIN:	20 ± 2 DB
GAIN BALANCE (1)	.6 DB RMS (1σ)
PHASE BALANCE (1)	4^{o} RMS (1σ)
RECEIVER PROTECTION:	20 WATTS PEAK AT 10 us DURATION

MIXER PHASE:

CHANNEL-TO-CHANNEL SIGNAL RF-TO-IF OUTPUT PHASE MATCHED WITH MIXER RF INPUT/LO INPUT PHASES UNIFORMLY DISTRIBUTED OVER 2π.

MIXER LO CARRIER SUPPRESSION 20 DB, MINIMUM

(1) GAIN AND PHASE OF RECEIVERS MUST TRACK WITHIN SPECIFIED TOLERANCE OVER THE MIDDLE THIRD OF THE RECEIVER BANDWIDTH (330 KHz $\pm 10\%$).

CALIBRATOR SPECIFICATIONS

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OPERATING TEMPERATURE RANGE: -20^{o} TO $+40^{o}C$

INPUTS: T.O.: 10 mw PEAK, MINIMUM, GATED OR CW

P_C = TRANSMITTER: 10 mw PEAK, MINIMUM, GATED

OUTPUT, REFERENCED TO P_C INPUT:

LEVELS: -15 DB TO -63 DB IN 3 DB STEPS

ACCURACIES: RMS (1σ) DEVIATION = $\pm$ .15 DB MAXIMUM

INPUT COMMAND: 5 BIT DIGITAL

PRE-PROCESSOR SPECIFICATIONS

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1. DIGITAL GAIN CONTROL

NOMINAL GAIN OF POST AMPLIFIER: 50 DB ± 3 DB MAXIMUM
DYNAMIC RANGE: 30 DB MAXIMUM
SENSOR INPUT DURATION: 25 us MINIMUM
SETTLING TIME: TBD
ACCURACY: .1 DB RMS (1σ)
MUTUAL DE-COUPLING: NOTE A

2. SYNCHRONOUS DOWN-CONVERSION (I/Q DETECTION) & VIDEO FILTER

MIXER LO CARRIER SUPPRESSION: 20 DB, MINIMUM
VIDEO FILTER BANDWIDTH: 275 KHz ±10%
QUADRATURE PHASE BALANCE: 3° RMS (1σ)
QUADRATURE GAIN BALANCE: .5 DB (1σ)
VIDEO OUTPUT CHANNEL-TO-CHANNEL BALANCE FOR VIDEO FREQUENCIES FROM DC TO 125 KHz:
PHASE: 4° RMS (1σ)
GAIN: .6 DB RMS (1σ)
MUTUAL DE-COUPLING: NOTE A

3. SAMPLE-AND-HOLD (S/H) DETECTION

APERTURE TIME: 100 NS MAXIMUM
SAMPLE TIME ERROR AND JITTER: 30 NS RMS (1σ)
MUTUAL DE-COUPLING: NOTE A

NOTE A: AT LEAST 50 DB MUTUAL ISOLATION BETWEEN RECEIVERS IN A COMMON MODULE AND 80 DB ISOLATION BETWEEN RECEIVERS IN SEPARATE MODULES; 10 RECEIVERS MAXIMUM PER MODULE.

4. MULTIPLEXERS AND A/D CONVERTERS
FORM: TIME MULTIPLEX OF 370 VIDEO CHANNELS
IN TWO CASCADED STAGES TO MULTIPLE PARALLEL A/D CONVERTER CHANNELS;
VIDEO CHANNELS/MULTIPLEX STAGE: 20 MAXIMUM
A/D CONVERTERS: 4 MINIMUM
BITS/COMPLEX WORD: 6I, 6Q
SAMPLE RATE: 7×10^6 COMPLEX WORDS/SECOND
DECOUPLING: 40 DB MINIMUM BETWEEN WORDS

5. A/D CONVERTER OUTPUT:
BIT SELECTION - 6 BITS I AND Q SELECTED FOR
5 MOST SIGNIFICANT OR 5 LEAST SIGNIFICANT
BITS I AND Q OUTPUT, DEPENDING UPON LOGIC COMMAND UPDATED AT BURST
RATE ($\sim$220 Hz).

6. BUFFER/FORMATTER:

INPUT DATA RATE: 28 x 10^6 MAXIMUM COMPLEX WORDS (5 BITS I, 5 BITS Q) PER SECOND
OUTPUT DATA RATE: 12.6 x 10^6 COMPLEX WORDS (5 BITS I, 5 BITS Q) PER SECOND
BUFFER DUTY FACTOR: .45 MAX WITH AVERAGING TIME OF 5 MS MAXIMUM

7. RECORDER:

RATE REQUIREMENTS: 150 MB/S, MAXIMUM
BIT ERROR RATE: 1 PART IN 10^5 (RANDOM)
RECORD TIME PER REEL: 30 MINUTES AT 120 MB/S
REEL SIZE, MAXIMUM: DIAMETER = 35 CM., WIDTH = 5 CM
REEL WEIGHT: 8.5 KG, MAX

8. CLUTTER RANGE TRACKER:

500 M. MAXIMUM RMS ERROR TO THE MEAN RANGE OF MAIN LOBE CLUTTER.*

9. DIFFERENTIAL CLUTTER RANGE SENSOR:

TO PRODUCE PROPERLY SIGNED MONOTONIC ERROR SIGNALS FOR 100 M. MINIMUM DIFFERENCES IN MEAN CLUTTER RANGES AT AZIMUTH ANGLES OF +20 $\pm 2^\circ$, 0°, -20 $\pm 2^\circ$ RELATIVE TO ARRAY BROADSIDE.*

---

* MEAN CLUTTER RANGE IS DEFINED AS THE NEAR RANGE TO THE MAIN LOBE CLUTTER SIGNALS 6 DB BELOW MEAN PEAK CLUTTER MAGNITUDE. THE SPECIFICATIONS ARE APPLICABLE TO GENERAL TERRAIN WITH AVERAGE SURFACE REFLECTIVITIES σ_0 = -15 DB AND FOR AVERAGING TIMES OF 1 SECOND, MINIMUM.

SUPPLEMENTARY MATERIAL

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DISPLAY POSSIBILITIES

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- CRT DISPLAY OF SELECTED CUTS THROUGH THE THREE-DIMENSIONAL DATA.
- DYNAMIC CRT DISPLAY, SHOWING CUT PASSING THROUGH THE DATA.
- DYNAMIC CRT DISPLAY, SHOWING DATA IN CONICAL FAN BEAM, DURING PROCESSING.
- THREE-DIMENSIONAL STEREOSCOPIC DISPLAY, WITH PERSPECTIVE AND VIEWING ANGLE CONTROLLED BY OPERATOR.

CONDUCTION COOLED SUBASSEMBLY

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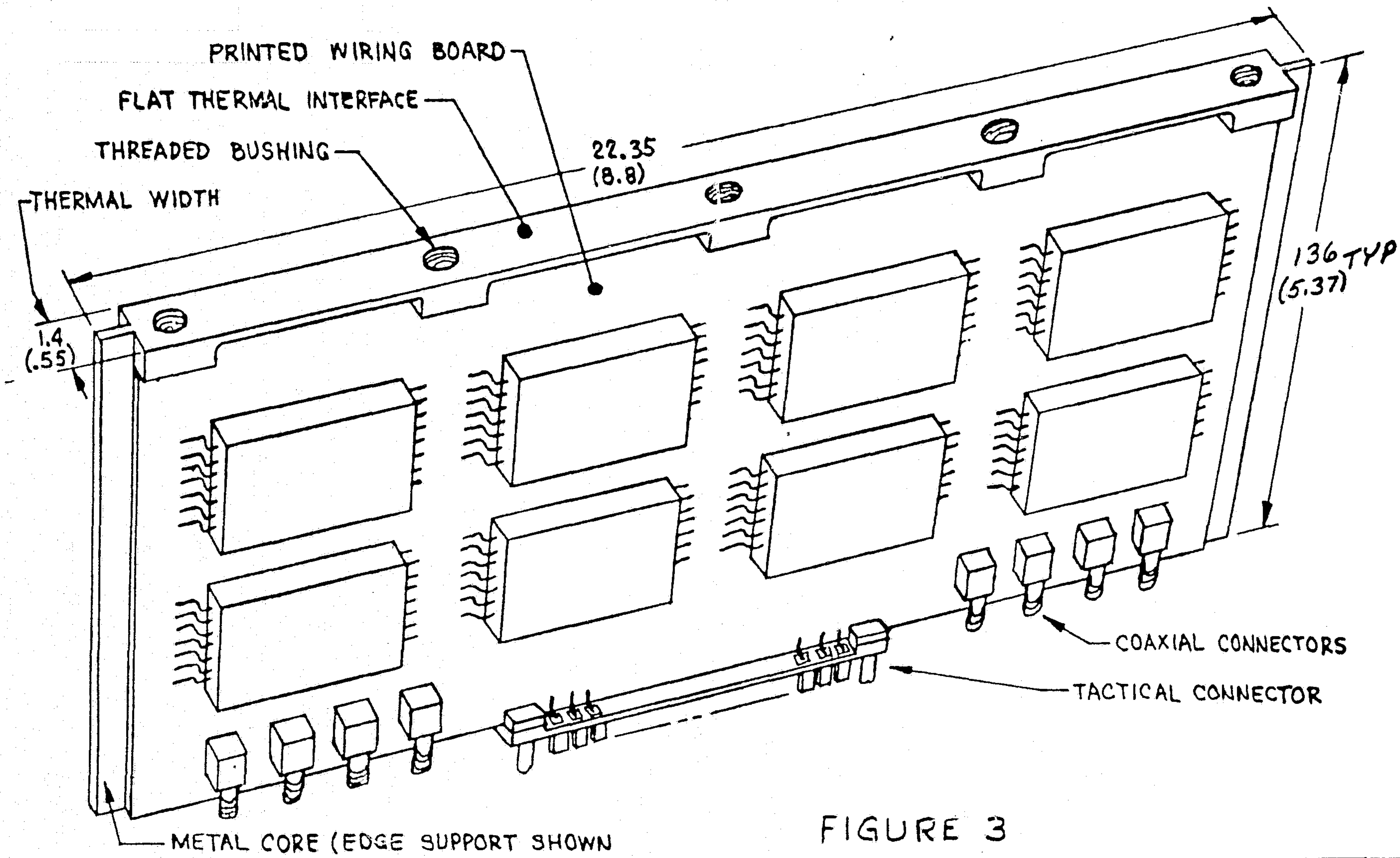

FIGURE 3

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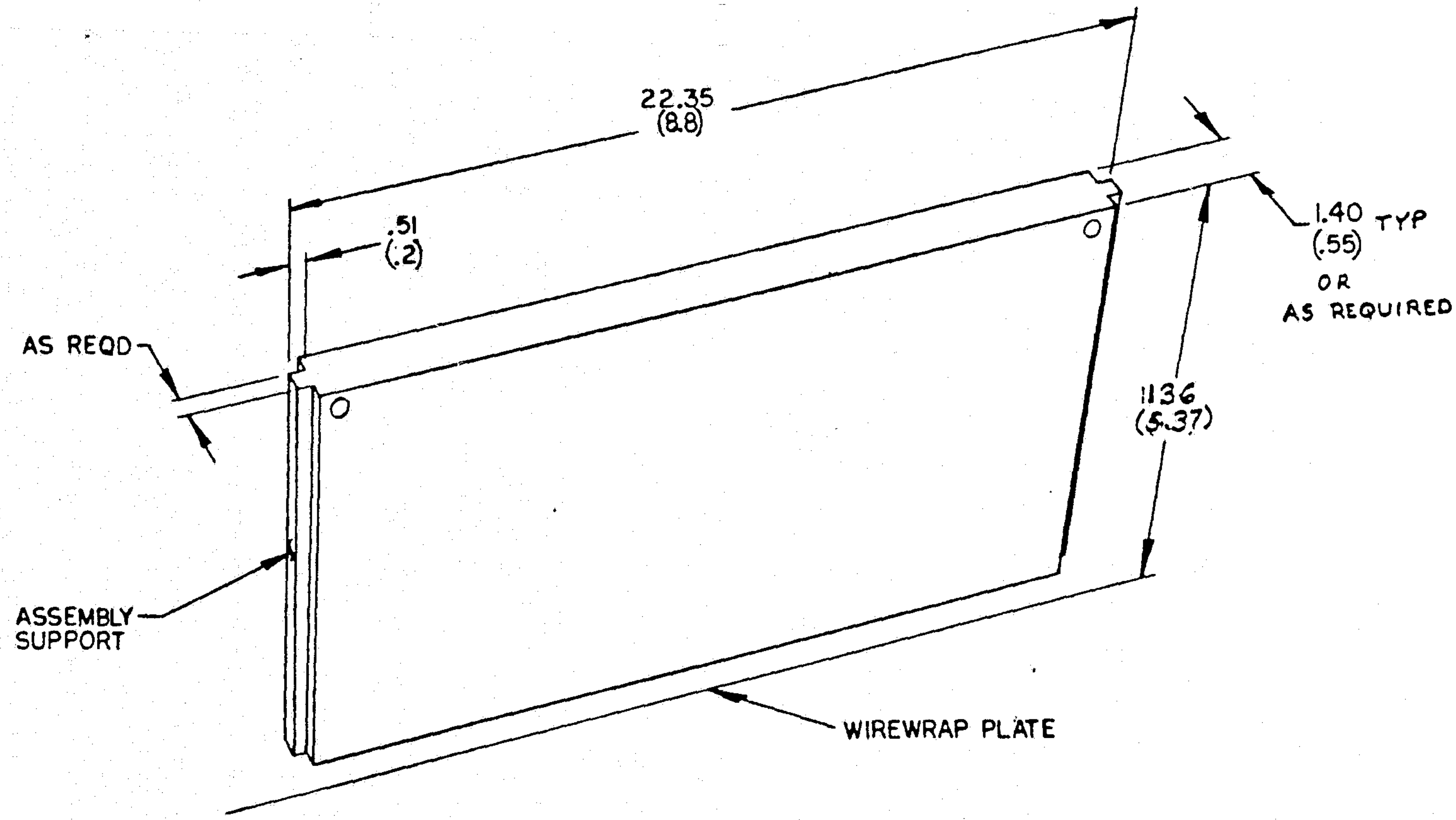

FIGURE 1.

STANDARD ELECTRONIC ENVELOPE
FOR 1.52 (.60) CENTERLINE PITCH.

FORCED AIR COOLED SUBASSEMBLY

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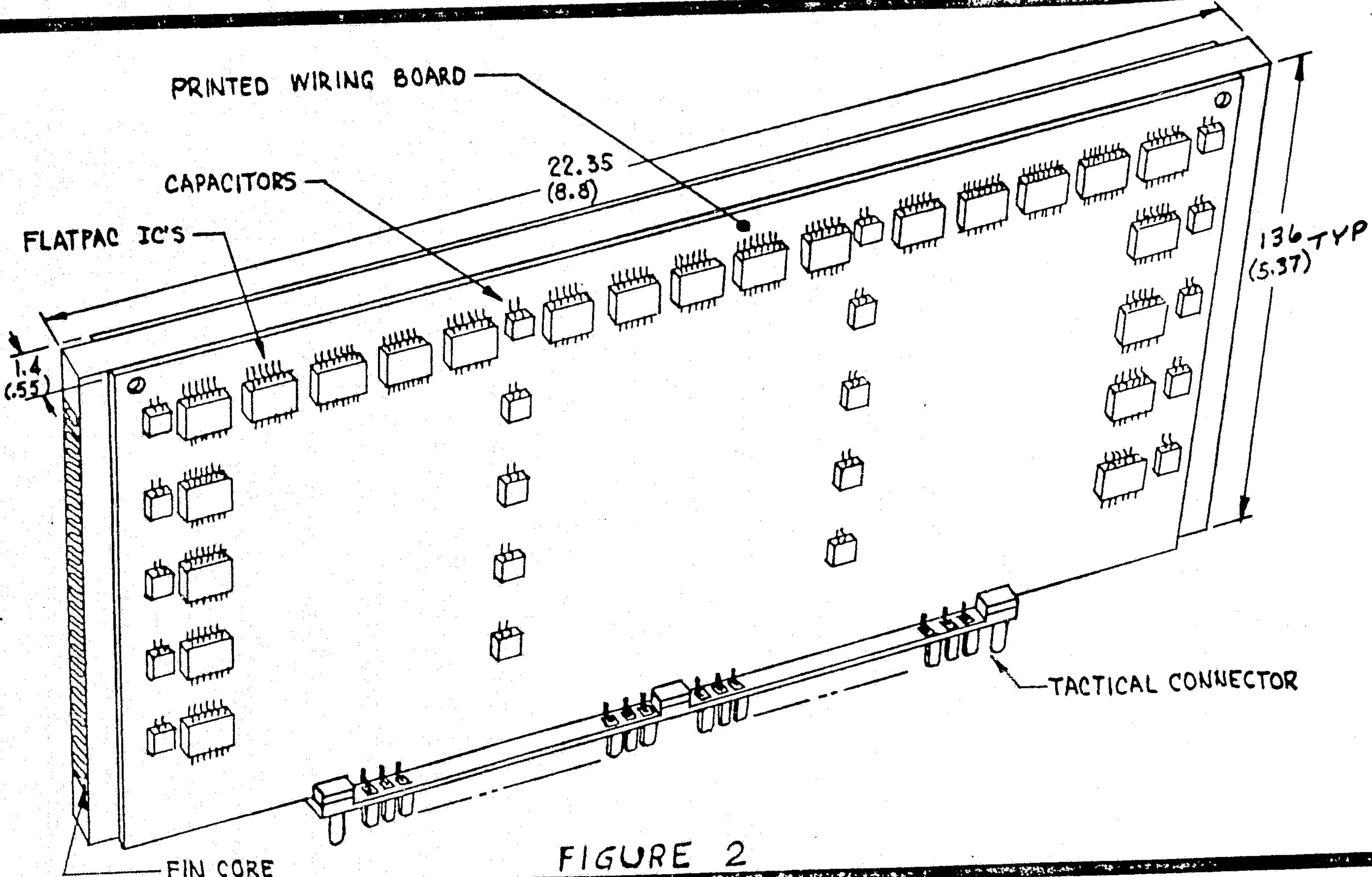

FIGURE 2

HEAT TRANSFER CHARACTERISTICS OF PARALLEL PLATES

TABLE 1

Equipment	Surface Size (IN)	Number of Screws (Peripheral)	Condition of Surface	Transfer Coefficient $\left(h = \frac{Watts}{IN^2\ {}^oC}\right)$
Subassy	.55 x 8.2	5	DRY	.46
			RTV-11	4.6,
Preprocessor	10 x 27	38	DRY	.02
			RTV-11	.11
Transmitter HVPS	17 x 22	42	DRY	.02
			RTV-11	.09
LVPS	10 x 12	22	DRY	.035
			RTV-11	.20
Exciter	10 x 20	30	DRY	.03
			RTV-11	.15
Transfer Plate	33 x 34	64	DRY	.015
			RTV-11	.07

HEAT TRANSFER CHARACTERISTICS OF CLAMPED PLATES

TABLE 2

Equipment	Contact Dims. (IN)	Area (IN^2)	Q (watts)	Peripheral Clamping: "h" with RTV11 $\left(\frac{W}{IN^2\ {}^oC}\right)$	Peripheral Clamping: *Δ T (^oC)	6 in x 6 in Area Clamping: "h" with RTV11 $\left(\frac{W}{IN^2\ {}^oC}\right)$	6 in x 6 in Area Clamping: *Δ T ^oC
Standard Subassy.	.55 x 8.2	4.5	35	4.6	≈ 2	4.6	≈ 2
Preprocessor	10 x 27	270	700	.11	24	.33	≈ 8
Transmitter HVPS	17 x 22	374	950	.09	28	.33	≈ 7
LVPS	10 x 12	120	380	.2	16	.33	≈10
Exciter	10 x 20	200	200	.15	7	.33	≈ 3
Transfer Plate	33 x 34	1172	800	.07	10	.33	≈ 2

$*\Delta T = \frac{Q}{Ah}$